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<b>(21) International Application Number:</b> PCT/US98/13046 <b>(22) International Filing Date:</b> 23 June 1998 (23.06.98)  <b>(30) Priority Data:</b> 08/881,189                      24 June 1997 (24.06.97)                      US  <b>(71) Applicants:</b> IMCLONE SYSTEMS INCORPORATED [US/US]; 180 Varick Street, New York, NY 10014 (US). REGENTS OF THE UNIVERSITY OF CALIFORNIA [US/US]; UCSD Technology Transfer Office, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0093 (US).  <b>(72) Inventors:</b> COLUCCI, M., Gabriella; Via Fossi, 51, I-82030 Dugenta (IT). CHRISPEELS, Maarten, J.; 8703 Glenwick Lane, La Jolla, CA 92037 (US). MOORE, Jeffrey, G.; 116 Pinehurst Avenue, New York, NY 10033 (US).  <b>(74) Agent:</b> FEIT, Irving, N.; Hoffmann & Baron, LLP, 350 Jericho Turnpike, Jericho, NY 11753 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>
<b>(54) Title:</b> NUCLEIC ACID ENCODING A LECTIN-DERIVED PROGENITOR CELL PRESERVATION FACTOR		
<b>(57) Abstract</b> <p>The invention relates to an isolated nucleic acid molecule that encodes a protein that is effective to preserve progenitor cells, such as hematopoietic progenitor cells. The nucleic acid comprises a sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof. The encoded protein has an amino acid sequence that comprises a sequence defined by SEQ ID NO:2, a homolog thereof, or a fragment thereof that contains an amino acid sequence TNNVLQVT. Methods of using the encoded protein for preserving progenitor cells <i>in vitro</i>, <i>ex vivo</i>, and <i>in vivo</i> are also described. The invention, therefore, includes methods such as myeloablation therapies for cancer treatment wherein myeloid reconstitution is facilitated by means of the specified protein. Other therapeutic utilities are also enabled through the invention, for example, expanding progenitor cell populations <i>ex vivo</i> to increase chances of engraftation, improving conditions for transporting and storing progenitor cells, and facilitating gene therapy to treat and cure a broad range of life-threatening hematologic diseases.</p>		

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**NUCLEIC ACID ENCODING A LECTIN-DERIVED**  
**PROGENITOR CELL PRESERVATION FACTOR**

**BACKGROUND OF THE INVENTION**

The invention relates to a nucleic acid and its corresponding protein for use in connection with the preservation of progenitor cells. More specifically, the invention relates to a nucleic acid and the protein that it encodes and which is capable of preserving progenitor cells, as well as a method of using the protein for preserving progenitor cells.

Each day the bone marrow generates and releases into the circulation several billion fully-differentiated, functional blood cells. Production of these cells derives from a small stock of quiescent progenitor cells (including the most primitive stem cells and other less primitive but still immature progenitors) by a process called hematopoiesis (Zipori 1992). The most primitive stem cells have the capacity to generate  $>10^{13}$  cells containing all blood lineages (Turhan et al. 1989). The production of such a large number of cells is achieved by extensive proliferation coupled with successive differentiation steps leading to a balanced production of mature cells. Progenitor cells progressively lose their capacity to generate multiple cells lineages and eventually produce cells of one or two cell lineages.

Soluble regulators and cell-cell interactions mediate differentiation pathways of immature progenitors through a tightly-controlled but inadequately understood process. Several of the body's soluble factors have been isolated and characterized both in culture and in animals (see, e.g., Ogawa (1993) and references therein). Regulators such as the colony stimulating factors (e.g., IL3, GM-CSF, G-CSF, M-CSF) not only induce proliferation and differentiation of progenitors capable of producing cells of either multiple cell lineages (IL3 and GM-CSF) or single cell lineages (G-CSF and M-CSF), but also preserve viability of their respective progenitors for short periods. Other regulators such as interleukin-1 (IL1), the kit ligand (KL), and thrombopoietin (Borge et al. 1996) increase viability of multipotential progenitors in addition to other functions. No known cytokines alone or in combination can preserve viability of primitive progenitors in liquid culture without stromal support beyond a few days.

Regulation of primitive stem cells appears to differ from that of immature, multilineage progenitors. Hematopoietic stem cells, which reside in the bone marrow predominantly in a quiescent state, do not appear to respond immediately to regulators that induce differentiation and proliferation. Maintenance of these cells in the body is mediated via cell-cell interactions and soluble regulators. Maintenance of quiescent stem cells *in vitro* has been achieved by culturing cells on adherent stromal layers with soluble regulators such as IL3, IL6, KL and LIF (Young et al. 1996). Recently, the addition of the FLK2/FLT3 ligand (FL) to this complex culture has been found to extend maintenance of quiescent stem cells from a few weeks to three months (Shah et al. 1996).

While the use of stromal cell culture has heretofore proven to be useful for the maintenance of hematopoietic stems cells in the laboratory setting, such approaches are not easily amenable to clinical application. Isolating and establishing stromal cell cultures for individual patients is not practical either because of time constraints or because a patient's marrow may be compromised by the underlying disease or exposure to agents (e.g., radiation, chemotherapy) that can damage the bone marrow microenvironment.

Lectins, defined as carbohydrate-binding proteins other than antibodies or enzymes, (Baronedes 1988), are widespread among plants, prokaryotes, and eukaryotes (see generally, Gabius et al. 1993). Each lectin recognizes a specific carbohydrate moiety, and forms a non-covalent bond with the carbohydrate through a stereochemical fit of complementary domains (e.g., hydrophobic pocket). Carbohydrates are widely present on cell surfaces (in the forms of glycoproteins, glycolipids, and polysaccharides), and appear to mediate cell-cell contacts including cell recognition (Sharon et al. 1989). Abnormal glycosylation patterns are associated with disease by causing alterations in a protein's surface properties, conformation, stability, or protease resistance (Dwek 1995).

Gowda et al. (1994) described the isolation of a mannose-glucose-specific lectin from the hyacinth bean (*Dolichos lab lab*). Purification and sequencing of this lectin is said to indicate that the protein includes two nonidentical subunits. The Gowda et al. publication describes evolutionary relationships of the lectin to other lectins, but does not ascribe any function to the protein beyond saccharide-binding.

Cell agglutinating properties of certain plant lectins have been known for over 100 years. Certain lectins have been used as tools in immunology laboratories as potent, specific

activators of T lymphocytes (phytohemagglutinin (PHA) and concanavalin A (ConA)) and B lymphocytes (pokeweed mitogen (PWM)) for over 30 years (Sharon et al. 1989). Some lectins have also been used to isolate hematopoietic progenitors for over 15 years (Gabius 1994a). Large numbers of cancer patients in Europe have received crude extracts of mistletoe lectin (*Viscum album*) intravenously as a candidate cancer therapy without major complications (Gabius 1994b). Whether these plant lectins act on mammalian cells via *de novo* means, or simply mimic their functional mammalian homologs is not yet known. No lectin has yet been successfully developed as a human therapeutic.

In view of the above considerations, it is clear that regulation of the hematopoietic process remains incompletely understood. Most soluble regulators identified, such as the colony stimulating factors and interleukins, induce proliferation and differentiation of progenitors cells in culture and their levels in the blood circulation increase during times of hematopoietic stress (e.g., blood loss, infection). For example, U.S. Patent No. 4,808,611 describes a method of using IL1 and a colony stimulating factor to induce proliferation and differentiation of hemopoietic stem cells. Some soluble regulators, such as IL1, IL6, IL11, KL, FL, and Tpo, marginally increase viability of primitive progenitors on their own, but when added in combination induce proliferation and differentiation of progenitors. Soluble regulators that maintain or expand primitive progenitors for extended periods in the absence of stromal support are not yet commercially available. As a consequence, numerous potential therapeutic approaches to diseases such as cancer and genetic blood diseases remain unexplored.

Accordingly, it is one of the purposes of this invention to overcome the above limitations in methods of regulating hematopoietic processes, by providing a factor and method of protecting, preserving, and expanding hematopoietic progenitor cell populations. It is another purpose of the invention to provide means for protecting the integrity of the hematopoietic processes *in vivo* as an adjunct to therapeutic treatments related to cancer and other diseases that can otherwise adversely impact upon the hematopoietic system.

### SUMMARY OF THE INVENTION

It has now been discovered that these and other objectives can be achieved by the present invention, which provides an isolated nucleic acid comprising a nucleotide sequence

as defined by SEQ ID NO:1, a homolog thereof, or a unique fragment thereof that encodes an amino acid sequence TNNVLQVT.

The isolated nucleic acid preferably encodes a mannose/glucose-specific legume lectin, and is more preferably isolated from a legume of the tribe Phaseoleae. Most preferably, the protein is encoded by a nucleic acid that is isolated from red kidney beans, white kidney beans, hyacinth beans, or black-eyed peas. The isolated nucleic acid of the invention preferably comprises a nucleotide sequence as defined by SEQ ID NO:1 or a unique fragment thereof.

Also, the protein encoded by the nucleic acid of the invention is capable of preserving progenitor cells that are at least unipotent progenitor cells, but the protein can be used to preserve pluripotent progenitor cells, as well as totipotent progenitor cells. In a preferred case, the protein can preserve hematopoietic progenitor cells, but progenitor cells from other tissues can also be preserved, including nerve, muscle, skin, gut, bone, kidney, liver, pancreas, or thymus progenitor cells. The progenitor cells capable of preservation according to the invention may express the CD34 antigen. More preferably, the progenitor cells express both CD34 and the FLK2/FLT3 receptor. Still more preferably, the progenitor cells express the FLK2/FLT3 receptor but do not express CD34. The protein can also be used to preserve cells that have been modified to express FLK2/FLT3 receptors on their surface. Thus, the invention provides a protein that has significant binding affinity for FLK2/FLT3 receptor on the cells, wherein binding of the protein with the FLK2/FLT3 receptor mediates the inhibition of differentiation of the cells.

The invention further provides a method for preserving progenitor cells, comprising contacting progenitor cells with a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, in an amount sufficient to preserve the progenitor cells.

The method of the invention is useful for preserving progenitor cells from other species, particularly mammalian species. The progenitor cells preferably comprise cells of hematopoietic origin. The method can be used for preserving any human progenitor cells that express the CD34 antigen and/or the FLK2/FLT3 receptor. Alternatively, the method can be

used to preserve any murine progenitor cells that express the Sca antigen, but that do not express mature blood cell lineage antigens.

The method can comprise contacting the progenitor cells with the protein *in vitro*, *ex vivo*, or *in vivo*. In addition, the method can further comprise contacting the progenitor cells with FLK2/FLT3 ligand in an amount sufficient to selectively expand the number of progenitor cells without inducing differentiation thereof.

In another embodiment, the invention is a method of treating a mammal in need of hematopoietic therapy, comprising:

a) obtaining a tissue sample from the mammal, the tissue sample comprising hematopoietic progenitor cells;

b) culturing the progenitor cells in the presence of a protein that preserves the progenitor cells, to provide cultured cells enriched in the progenitor cells, wherein the protein is encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT;

c) subjecting the mammal to conditions sufficient to effect myeloablation; and  
d) administering the cultured cells to the mammal following the myeloablation to reconstitute the hematopoietic system of the mammal.

According to the method, the myeloablation conditions can comprise bone marrow irradiation, whole body irradiation, or chemically-induced myeloablation.

In another embodiment, the invention is a method of enriching progenitor cells, comprising culturing progenitor cells in a progenitor-preserving amount of a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, wherein the protein specifically preserves the progenitor cells, and wherein the culturing is performed under conditions permitting preservation of progenitor cells while permitting the number of differentiated cells to decrease.

The method can be used to enrich progenitor cells, such as primitive progenitor cells, as well as mature progenitor cells. Preferably, the progenitor cells are at least substantially free of stromal cells.

The culturing conditions used in the method can include culturing in a medium containing a cytotoxic agent that exhibits selective toxicity for proliferating cells. Suitable cytotoxic agents include, for example, adriamycin, cyclophosphamide, taxol or other taxane, cisplatin, or 5-fluorouracil.

5 In still another embodiment, the invention is a method of improving hematopoietic competence in a mammal, comprising:

a) culturing a tissue sample comprising hematopoietic progenitor cells in a growth medium containing a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, in an amount sufficient to preserve the progenitor cells and to provide cultured cells enriched in the progenitor cells; and

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b) transfusing the enriched cultured cells to the mammal to provide progenitor cells for generating blood cellular components in the mammal.

According to the method, the tissue sample can comprise peripheral blood, umbilical cord blood, placental blood, or bone marrow. Preferably, the tissue sample is autologous to the mammal. It is also preferred that the tissue sample is at least substantially free of stromal cells. The method can further comprise ablating hematopoietic tissues in the mammal prior to the transfusing.

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In yet a further embodiment, the invention is an improvement to a method of transfecting an exogenous DNA sequence into somatic cells, in which the improvement comprises transfecting progenitor cells selectively preserved by a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT.

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In another embodiment, the invention is a composition for preserving viability of progenitor cells ex vivo, comprising a cell growth medium and a protein that preserves progenitor cells, wherein the protein is encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT.

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In a still further embodiment, the invention is a method for preserving progenitor cells in a mammal, comprising:

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a) administering to the mammal a protein that specifically preserves progenitor cells, the protein being encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, in an amount sufficient to preserve progenitor cells of the mammal in a substantially non-proliferative state;

b) exposing the mammal to myeloablative conditions sufficient to effect ablation of proliferating myeloid cells but sparing non-proliferating progenitor cells; and

c) following the exposing, reestablishing proliferation or differentiation of the preserved progenitor cells.

According to the method, the reestablishing can comprise administering to the mammal a cytokine in an amount sufficient to improve the viability of the progenitor cells. The viability-improving cytokine can be IL-1, IL-3, IL-6, IL-11, KL, or a combination thereof. The method can be further modified such that the reestablishing comprises administering to the mammal a proliferation-stimulating amount of the FLK2/FLT3 ligand.

These and other advantages of the present invention will be appreciated from the detailed description and examples that are set forth herein. The detailed description and examples enhance the understanding of the invention, but are not intended to limit the scope of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention have been chosen for purposes of illustration and description, but are not intended in any way to restrict the scope of the invention. The preferred embodiments of certain aspects of the invention are shown in the accompanying drawings, wherein:

Figure 1 is a map of a cloning vector pCR2.1-DLA manufactured by ligating a cDNA according to the invention in the *EcoRI* site of the cloning vector pCR2.1.

Figure 2 is a direct amino acid sequence comparison of the mannose lectin described by Gowda et al. (1994) and the derived amino acid sequence of the protein encoded by the nucleic acid of the invention.

Figure 3 is a map of a cloning vector pCR2.1-DLA(D) manufactured by ligating a mutated cDNA in the *EcoRI* site of the cloning vector pCR2.1.

Figure 4 is a map of a cloning vector pBS-SpDLA manufactured by ligating a recombinant fragment in the *EcoRI* site of the cloning vector pBluescript SK+.

Figure 5 is a map of a cloning vector pCR2.1-SpM1(D) manufactured by ligating a mutated recombinant clone in the *EcoRI* site of the cloning vector pCR2.1.

5 Figure 6 is a map of a recombinant expression vector pBIN-VicPro manufactured by subcloning the vicilin promoter obtained from the pCW66 vector in the *EcoRI/ClaI* site of the plant binary vector pBIN19 for *Agrobacterium*-mediated transformation.

10 Figure 7 is a map of a recombinant expression vector pBINVicPro-SpDLA manufactured by ligating a recombinant fragment in the *EcoRI/SacI* site of the pBINVicPro vector.

Figure 8 is a map of a recombinant expression vector pBINVicPro-SpDLA(D) manufactured by ligating a mutated recombinant clone in the *EcoRI* site of the pBINVicPro vector.

15 Figure 9 is a map of a recombinant expression vector pGEX4T-1-DLA manufactured by ligating a wild-type cDNA clone in the *EcoRI/SalI* site of the *E. coli* expression vector pGEX4T-1.

Figure 10 is a map of a recombinant expression vector pGEX4T-1-DLA(D) manufactured by ligating a mutant cDNA clone in the *EcoRI/XhoI* site of the *E. coli* expression vector pGEX4T-1.

20 Figure 11 is an electrophoretogram of a Southern blot of total protein extracts of *E. coli* cells transformed with the recombinant expression vectors pGEX4T-1-DLA and pGEX4T-1-DLA(D).

Figure 12 is an electrophoretogram of a Western blot of purified GST-fusion proteins with and without cleavage by thrombin.

25 Figure 13A is a graph showing that a crude extract of an *E. coli* culture containing expressed FRIL specifically stimulates hFLK2/FLT3 3T3 cells; Figure 13B is a graph showing that the same extract does not stimulate untransfected 3T3 cells.

30 Figure 14A is a histogram showing that purified recFRIL preserves cord blood mononuclear cells in a dose-responsive manner; Figure 14B is a histogram showing that purified recFRIL preserves hematopoietic progenitors in a dose-responsive manner.

Figure 15 is a histogram showing that the protein encoded by a nucleic acid of the invention is sufficient to preserve progenitor cells *in vitro*, whereas a cytokine cocktail fails to preserve such cells.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is directed to an isolated nucleic acid encoding a protein that preserves progenitor cells, and, therefore, the invention further includes a method of using the nucleic acid in producing the encoded protein, and a method of using the encoded protein in preserving progenitor cells.

Applicants have isolated and sequenced a nucleic acid having the sequence defined by SEQ ID NO:1, and homologs thereof, including homologs in other species. The invention further comprises unique fragments of the nucleic acid of SEQ ID NO:1 and its homologs.

The protein encoded by the nucleic acid sequence defined by SEQ ID NO:1 has the amino acid sequence defined by SEQ ID NO:2. But the invention also encompasses isolated nucleic acid molecules that encode unique portions of the protein specified as SEQ ID NO:2. Specifically, the invention includes nucleic acids that encode proteins that contain the sequence TNNVLQVT, which is a part of SEQ ID NO:2, as well as functional equivalents thereof.

"Nucleic acid," as used herein, means any deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) that encodes in its nucleotide sequence a protein as described herein or a unique fragment thereof. The fragment can be an oligonucleotide (i.e., about 8 to about 50 nucleotides in length) or a polynucleotide (about 50 to about 2,000 or more nucleotides in length). For example, nucleic acids include messenger RNA (mRNA), complementary DNA (cDNA), genomic DNA, synthetic DNA or RNA, and the like. The nucleic acid can be single stranded, or partially or completely double stranded (duplex). Duplex nucleic acids can be homoduplex or heteroduplex.

The invention specifically includes nucleic acids that have a nucleotide sequence including the sequence defined by SEQ ID NO:1, or a homolog thereof, or unique fragments thereof. In the present specification, the sequence of a nucleic acid molecule that encodes the protein is considered homologous to a second nucleic acid molecule if the nucleotide sequence of the first nucleic acid molecule is at least about 30% homologous, preferably at least about 50% homologous, and more preferably at least about 65% homologous to the sequence of the second nucleic acid molecule. In the case of nucleic acids having high homology, the nucleotide sequence of the first nucleic acid molecule is at least about 75% homologous, preferably at least about 85% homologous, and more preferably at least about

95% homologous to the nucleotide sequence of the second nucleic acid molecule. For example, a test for homology of two nucleic acid sequences is whether they hybridize under normal hybridization conditions, preferably under stringent hybridization conditions.

Given the nucleic acid sequence disclosed herein, the artisan can further design nucleic acid structures having particular functions in various types of applications. For example, the artisan can construct oligonucleotides or polynucleotides for use as primers in nucleic acid amplification procedures, such as the polymerase chain reaction (PCR), ligase chain reaction (LCR), Repair Chain Reaction (RCR), PCR oligonucleotide ligation assay (PCR-OLA), and the like. Oligonucleotides useful as probes in hybridization studies, such as *in situ* hybridization, can be constructed. Numerous methods for labeling such probes with radioisotopes, fluorescent tags, enzymes, binding moieties (e.g., biotin), and the like are known, so that the probes of the invention can be adapted for easy detectability.

Oligonucleotides can also be designed and manufactured for other purposes. For example, the invention enables the artisan to design antisense oligonucleotides, and triplex-forming oligonucleotides, and the like, for use in the study of structure/function relationships. Homologous recombination can be implemented by adaptation of the nucleic acid of the invention for use as targeting means.

As a new and specific nucleotide sequence is disclosed herein, the artisan will recognize that the nucleic acid can be produced by any synthetic or recombinant process such as is well known in the art. Nucleic acids according to the invention can further be modified to alter biophysical or biological properties by means of techniques known in the art. For example, the nucleic acid can be modified to increase its stability against nucleases (e.g., "end-capping"), or to modify its lipophilicity, solubility, or binding affinity to complementary sequences. Methods for modifying nucleic acids to achieve specific purposes are disclosed in the art, for example, in Sambrook et al. (1989) and , the disclosure of which is incorporated by reference herein. Moreover, the nucleic acid can include one or more portions of nucleotide sequence that are non-coding for the protein of interest.

The skilled artisan appreciates that, if an amino acid sequence (primary structure) is known, a family of nucleic acids can then be constructed, each having a sequence that differs from the others by at least one nucleotide, but where each different nucleic acid still encodes the same protein. For example, if a protein has been sequenced but its corresponding gene

has not been identified, the gene can be acquired through amplification of genomic DNA using a set of degenerate primers that specify all possible sequences encoding the protein.

The protein encoded by the nucleic acid of the invention, and functional analogs of the encoded protein, are essentially pure. For the purposes of this specification, "essentially pure" means that the protein and functional analogs are free from all but trace amounts of other proteins as well as of materials used during the purification process. A protein is considered to be essentially pure if it is at least 85%, preferably at least 90%, and more preferably at least 95% pure. Methods for purifying proteins are known in the art.

Determination of whether two amino acid sequences are substantially homologous is, for the purpose of the present specification, based on FASTA searches in accordance with Pearson et al. (1988). In the present specification, the amino acid sequence of a first protein is considered to be homologous to that of a second protein if the amino acid sequence of the first protein has at least about 20% amino acid sequence identity, preferably at least about 40% identity, and more preferably at least about 60% identity, with the sequence of the second protein. In the case of proteins having high homology, the amino acid sequence of the first protein has at least about 75% sequence identity, preferably at least about 85% identity, and more preferably at least about 95% identity, with the amino acid sequence of the second protein.

The protein encoded by the nucleic acid of the present invention further includes functional homologs. A protein is considered a functional homolog of another protein for a specific function, as described below, if the homolog has the same function as the other protein. The homolog can be, for example, a fragment of the protein, or a substitution, addition, or deletion mutant of the protein.

As is also known, it is possible to substitute amino acids in a sequence with equivalent amino acids. Groups of amino acids known normally to be equivalent are:

- (a) Ala(A), Ser(S), Thr(T), Pro(P), Gly(G);
- (b) Asn(N), Asp(D), Glu(E), Gln(Q);
- (c) His(H), Arg(R), Lys(K);
- (d) Met(M), Leu(L), Ile(I), Val(V); and
- (e) Phe(F), Tyr(Y), Trp(W).

Substitutions, additions, and/or deletions in the amino acid sequences can be made as long as the protein encoded by the nucleic acid of the invention continues to satisfy the functional criteria described herein. An amino acid sequence that is substantially the same as another sequence, but that differs from the other sequence by means of one or more  
5 substitutions, additions, and/or deletions, is considered to be an equivalent sequence. Preferably, less than 50%, more preferably less than 25%, and still more preferably less than 10%, of the number of amino acid residues in a sequence are substituted for, added to, or deleted from the protein encoded by the nucleic acid of the invention.

As used herein, "progenitor cell" refers to any normal somatic cell that has the  
10 capacity to generate fully differentiated, functional progeny by differentiation and proliferation. Progenitor cells include progenitors from any tissue or organ system, including, but not limited to, blood, nerve, muscle, skin, gut, bone, kidney, liver, pancreas, thymus, and the like. Progenitor cells are distinguished from "differentiated cells," the latter being defined as those cells that may or may not have the capacity to proliferate, i.e., self-replicate, but that  
15 are unable to undergo further differentiation to a different cell type under normal physiological conditions. Moreover, progenitor cells are further distinguished from abnormal cells such as cancer cells, especially leukemia cells, which proliferate (self-replicate) but which generally do not further differentiate, despite appearing to be immature or undifferentiated.

20 Progenitor cells include all the cells in a lineage of differentiation and proliferation prior to the most differentiated or the fully mature cell. Thus, for example, progenitors include the skin progenitor in the mature individual. The skin progenitor is capable of differentiation to only one type of cell, but is itself not fully mature or fully differentiated.

25 Production of some mature, functional blood cells results from proliferation and differentiation of "unipotential progenitors," i.e., those progenitors that have the capacity to make only one type of blood cell. For red blood cell (erythrocyte) production, a unipotential progenitor called a "CFU-E" (colony forming unit-erythroid) has the capacity to generate two to 32 mature progeny cells.

30 Various other hematopoietic progenitors have been characterized. For example, hematopoietic progenitor cells include those cells that are capable of successive cycles of differentiating and proliferating to yield up to eight different mature hematopoietic cell

lineages. At the most primitive or undifferentiated end of the hematopoietic spectrum, hematopoietic progenitor cells include the hematopoietic "stem cells." These rare cells, which represent from about 1 in 10,000 to about 1 in 100,000 of the cells in the bone marrow, and the most primitive cells have the capacity to generate  $>10^{13}$  mature blood cells of all lineages and are responsible for sustaining blood cell production over the life of an animal. They reside in the marrow primarily in a quiescent state, and may form identical daughter cells through a process called "self-renewal." Accordingly, such uncommitted progenitor cells can be described as being "totipotent," i.e., both necessary and sufficient for generating all types of mature blood cells. Progenitor cells that retain a capacity to generate all blood cell lineages but that can not self-renew are termed "pluripotent." Cells that can produce some but not all blood lineages and can not self-renew are termed "multipotent."

The protein encoded by the nucleic acid of the invention is useful to preserve any of these progenitor cells, including unipotent progenitor cells, pluripotent progenitor cells, multipotent progenitor cells, and/or totipotent progenitor cells. The protein is useful in the preservation and maintenance of progenitor cells in hematopoietic tissues as well as in non-hematopoietic tissues, such as those mentioned above.

The recombinant protein encoded by the nucleic acid of the invention is especially useful in preserving hematopoietic progenitors in mammals such as humans, mice, rats, etc. In the human, hematopoietic progenitor cells can be identified as belonging to a class of cells defined by their expression of a cell surface antigen designated CD34. These cells may be referred to as "CD34<sup>+</sup>" cells. In the mouse, hematopoietic progenitor cells may be referred to as "Sca<sup>+</sup>Lin<sup>-</sup>" cells, reflecting their cell surface antigen signature. Other mammalian species exhibit similar signature properties identifying hematopoietic progenitor cells.

Hematopoietic progenitors can also be identified by their expression of the FLK2/FLT3 receptor.

Human hematopoietic progenitor cells that express the CD34 antigen and/or the FLK2/FLT3 receptor are referred to herein as "primitive progenitor cells." Therefore, primitive progenitor cells include CD34<sup>+</sup>FLK2/FLT3<sup>-</sup> cells, CD34<sup>-</sup>FLK2/FLT3<sup>+</sup> cells, and CD34<sup>+</sup>FLK2/FLT3<sup>+</sup> cells. By contrast, hematopoietic cells that do not express either the CD34 antigen or the FLK2/FLT3 receptor (i.e., CD34<sup>-</sup>FLK2/FLT3<sup>-</sup> cells) are referred to as "mature progenitor cells."



Preferably, the recombinant protein is effective to preserve progenitor cells that express the CD34 antigen and/or the FLK2/FLT3 receptor. The progenitor cells can include cells modified to express the CD34 antigen or FLK2/FLT3 receptors on their surface. In a preferred case, the protein has significant binding affinity for FLK2/FLT3 receptor on the cells, wherein binding of the protein with the FLK2/FLT3 receptor mediates the inhibition of differentiation of the cells. The protein encoded by the nucleic acid of the invention has been designated "FLK2/FLT3 Receptor-Interacting Lectin," abbreviated "FRIL," to describe this phenomenon, but this designator is used for convenience and should not be understood to definitionally ascribe any specific property to, or any origin of, the protein.

The recombinant protein mediates "preservation" of progenitor cells. By this is meant that the protein inhibits differentiation of the progenitor cells without depleting the progenitor cell population. In some cases, the inhibition of differentiation is accompanied by proliferation of the progenitor cell population. In other cases, the inhibition of differentiation is induced without proliferation of the progenitor cell population. In particular, by inhibiting differentiation processes, it is meant that the peptide significantly lowers the rate at which cells differentiate, and it may in fact completely stop these processes. While the mechanism by which the protein acts is not itself understood, one theoretical possibility is that the protein maintains progenitor cells in a quiescent or G0 state of the cell cycle. Regardless of the actual mechanism of its action, however, the protein does preserve progenitor cells without killing the cells in significant numbers. In this sense, the recombinant protein is significantly distinguished from factors that inhibit or interfere with cellular processes (e.g., DNA replication, protein synthesis), and that thereby induce significant cell mortality.

As a result of the present invention, numerous utilities become technically feasible. The method of the invention can include contacting the progenitor cells with the recombinant protein *in vitro*, *ex vivo*, or *in vivo*. "*In vitro*" methods include methods such as laboratory experimental methods which are performed wholly outside a living body. While cells can be acquired from a living organism for use *in vitro*, it is understood that the cells will not be returned to the body. *In vitro* methods are commonly employed in experimental settings to advance understanding of particular systems. "*Ex vivo*" methods include clinical methods in which cells are manipulated outside the body of an organism, e.g., a patient, with the specific purpose of reimplanting some cells back into the organism to achieve a desired therapeutic

purpose. "*In vivo*" methods are performed within the body of the organism, without requiring explantation or tissue sampling and manipulation.

For example, the recombinant protein finds a utility, *inter alia*, in that it enables *ex vivo* preservation of hematopoietic progenitor cells isolated from either normal or malignant (e.g., leukemic) bone marrow. Accordingly, the protein can be employed in the culture of mononuclear cells derived from a source of such cells, for example, from bone marrow, umbilical cord blood, placental blood, or peripheral blood. Alternatively, the recombinant protein can be used in conjunction with growth factors such as colony stimulating factors (CSFs) (e.g., IL3, GM-CSF, G-CSF, M-CSF), interleukins (e.g., IL1 through IL18) and KL *in vitro* to selectively induce proliferation and terminal differentiation of mature progenitors while preserving a significantly enriched population of primitive progenitors. U.S. Patent Nos. 5,472,867 and 5,186,931 describe representative methods of using CSFs and interleukins (ILs) to expand progenitor cell populations in the contexts of, respectively, cancer chemotherapy and bone marrow transplants. In a preferred case according to the present invention, the method can further includes contacting the progenitor cells with FLK2/FLT3 ligand in an amount sufficient to selectively expand the number of progenitor cells without inducing differentiation thereof.

The recombinant protein also enhances survival of progenitor cells when cultured *in vitro*. For example, a process of *in vitro* selection can be used that involves using the protein to preserve progenitor cells in a substantially quiescent state in culture, while using a cytotoxic agent that exhibits selective toxicity for proliferating cells, e.g., to kill cells passing through cell cycle ("cycling cells"). Suitable cytotoxic agents include, for example, compounds such as adriamycin, cyclophosphamide, taxol or other taxane, cisplatin, 5-fluorouracil, and the like. The method is useful to preserve quiescent progenitor cells. The method is effective even when the progenitor cells are substantially free of stromal cells, which are considered to normally be necessary for progenitor cell maintenance and proper hematopoietic reconstitution. The recombinant protein improves the ability to functionally select stem cells either alone or with other factors. Such functional selection methods, include the method reported by Berardi et al. (1995) where selection is made using a combination of KL and IL3 with 5-FU.

By preserving progenitor cells in a quiescent state, the protein encoded by the nucleic acid of the invention preserves normal progenitor cells, while the cycling cells are killed. For example, *ex vivo* purging protocols can be used to selectively eliminate neoplastic cells by targeting the elimination of actively cycling cells. Once the progenitors cells have been  
5 purged of malignant cycling cells, they can be returned to the patient, and permitted to resume normal proliferation and differentiation. In one especially useful scenario, the recombinant protein allows for functional selection of normal progenitor cells from a leukemic bone marrow.

Such functional selection and purification of primitive stem cells can also be used to  
10 enable allogeneic transplant procedures. In situations where autologous tissue is not available for transplant, culturing allogeneic cells in the presence of the protein encoded by the nucleic acid of the invention will result in the selection of stem cells and depletion of T lymphocytes and other effector cells. This will enable transplant of progenitors while inhibiting a graft versus host reaction. Such stem cells acquire within the recipient immunological tolerance of  
15 the recipient's histocompatibility antigens.

It is a further advantage of the invention that it enables preservation of cells for periods and under conditions that permit shipment of cells, e.g., by mail, to distant locations for transplantation.

The recombinant protein also enables *ex vivo* manipulation of hematopoietic  
20 progenitor cells for use in gene therapy by preserving cells in liquid culture. For example, by preserving hematopoietic progenitor cells in culture for more than two weeks, the protein enables increased targeting efficiency by viral vectors that enter non-replicating cells (e.g., vectors such as adeno-associated viruses), and provides longer periods for the evaluation of the resultant cell populations to determine efficiency of transfection. Thus, in another  
25 embodiment, the method can be used in conjunction with methods of transfecting an exogenous DNA sequence into somatic cells. The method can then include transfecting progenitor cells selectively preserved by the recombinant protein.

The invention also has utility in conjunction with therapies, e.g., cancer therapies, which employ irradiation. Specifically, because the recombinant protein preserves progenitor  
30 cells in a quiescent state, administration of the recombinant protein to a mammalian subject *in vivo* allows the use of increased levels of total body irradiation to eliminate neoplastic cells,

while leaving quiescent cells relatively unaffected. The protein can be employed in conjunction with other cytoprotective substances such as IL-1 to obtain an enhanced or complementary effect.

Thus, the method can involve treating a mammalian subject in need of hematopoietic therapy. In particular, the recombinant protein can be used to improve hematopoietic competence in a mammal, i.e., the mammal's ability to generate functional mature blood elements. For example, a tissue sample including hematopoietic progenitor cells can be obtained from the subject. Then the tissue sample can be cultured *ex vivo* in a growth medium containing the recombinant protein to preserve the progenitors, while allowing cycling cells to proliferate, differentiate and die. The cultured cells become significantly enriched in the primitive progenitor cells. Meanwhile, the mammal can be subjected to conditions sufficient to effect myeloablation, e.g., bone marrow irradiation, whole body irradiation, or chemically-induced myeloablation. Finally, the progenitor-enriched cultured cells can be administered or transfused to the mammal following the myeloablation to generate blood cellular components in the mammal, thereby reconstituting the hematopoietic system of the mammal. The method can use a tissue sample comprising peripheral blood, umbilical cord blood, placental blood, or bone marrow. Preferably, the tissue sample is autologous to the mammal. The tissue sample can also be at least substantially free of stromal cells.

While described here as an autologous procedure, the skilled practitioner will recognize that the methods can be readily adapted to transplant of progenitor-enriched cells from one individual to another. Again, when autologous tissue is not available for transplant, culturing allogeneic cells in the presence of the encoded protein can be used to induce selection of stem cells and depletion of T lymphocytes and other effector cells. The transplanted progenitor cells acquire within the recipient immunological tolerance of the recipient's histocompatibility antigens, thereby mitigating graft vs. host reactions.

The invention further includes a composition for preserving viability of progenitor cells *ex vivo* or *in vitro*. The composition comprises a culture medium suitable for growth and maintenance of mammalian cells in culture, along with an amount of the recombinant protein sufficient to preserve progenitor cells as described herein. Virtually any cell or tissue culture medium can be modified for the preservation of progenitors in this way. Suitable

standardized culture media are known, including, for example, Minimum Essential Medium Eagle's (MEM), Dulbecco's Modified Eagle's Medium (DMEM), McCoy's 5A Modified Medium, Iscove's Modified Dulbecco's Medium (IMDM), Medium 199, RPMI-1640, specialized variant formulations of these media, and the like. Such media can be supplemented using sera (e.g., fetal bovine serum) buffers (e.g., HEPES), hormones, cytokines, growth factors, or other desired components. Numerous media are available commercially, e.g., from Sigma Chemical Co., St. Louis, MO.

Ready-to-use receptacles, e.g., blood bags, media bags and bottles, microtiter plates, tissue and cell culture flasks, roller bottles, shake flasks, culture dishes, and the like, can also be provided with the protein encoded by the nucleic acid of the invention (with or without culture medium or other active components) to promote storage and/or culture of progenitor cells. The protein allows the artisan to store progenitor cells under refrigeration, at ambient temperature, or in an incubator at 37°C. The ability of the protein to preserve cells at ambient temperatures is particularly useful for transporting cells.

Also, the invention includes a method for preserving progenitor cells in a mammal *in vivo*. In this approach, the method comprises administering to the mammal the recombinant protein in an amount sufficient to preserve progenitor cells of the mammal in a substantially non-proliferative state. The mammal is then exposed to myeloablative conditions sufficient to effect ablation of proliferating myeloid cells but sparing non-proliferating progenitor cells. Following the ablative treatment, proliferation or differentiation of the preserved progenitor cells is reestablished, usually by administering to the mammal a cytokine in an amount sufficient to improve the viability of the progenitor cells. Preferred viability-improving cytokines include, for example, FLK2/FLT3 ligand, IL1, IL3, IL6, IL11, KL, or a combination thereof. According to this method, the recombinant protein can be used to enhance autologous bone marrow transplantation techniques in which lethal doses of radiation and/or chemotherapy are followed by reinfusion of stored marrow.

An effective amount of recombinant protein can be administered to a mammal by any convenient approach, such as parenteral routes, e.g., intravenous injection, or enteral routes, e.g., oral administration. Oral administration routes are expected to be useful since natural source lectins typically resist oral/gastric degradation, and can exhibit substantial bioavailability by this approach (Pusztai et al. 1995). The skilled artisan recognizes the

utility and limitations of various methods of administration and can adjust dosage accordingly.

Other therapeutic utilities also present themselves to the skilled practitioner as being enabled by the invention. Such other utilities include, for example, expanding progenitor cell populations *ex vivo* to increase chances of engraftation, improving conditions for transporting and storing progenitor cells, and removing a fundamental barrier to enable gene therapy to treat and cure a broad range of life-limiting hematologic diseases such as sickle cell anemia and thalassemia.

The protein encoded by the nucleic acid of the invention can also be used as a specific probe for the identification or localization of progenitor cells. Since the protein binds specifically to primitive progenitor cells, a composition including the protein linked to a detectable moiety such as a fluorescent marker can be used to specifically label and identify progenitor cells. Thus, cell sorting to isolate progenitor cells can be performed, as can histologic localization of progenitor cells in tissues, and other methods known in the art. The skilled artisan can select the type or marker moiety to be employed and the method of isolating cells according to the task to be performed, since numerous methods of labeling proteins are known in the art.

The protein encoded by the nucleic acid of the invention can be used to isolate FLK2/FLT3-R-expressing progenitor cells. The protein is preferably linked to a chemical group or to an object to assist in the isolation. For example, the protein can be chemically linked to magnetic beads. The multivalent nature of the protein is particularly useful for isolation of cells, such as primitive hematopoietic progenitors, which express low levels of FLK2/FLT3-R (i.e., less than about 5,000 receptors/cell). Similar methods using antibodies linked to magnetic beads require significantly higher levels of cell surface receptors.

#### Making and Using the Nucleic Acid of the Invention

The nucleic acid sequence of the invention can be isolated from a natural source, such as being derived from legume plants. Legumes such as the garden pea or the common bean are plants ("leguminous plants") from a family (*Leguminosae*) of dicotyledonous herbs, shrubs, and trees bearing (nitrogen-fixing bacteria) nodules on their roots. These plants are commonly associated with their seeds (e.g., such as the garden pea or the common bean, etc.).

More specifically, the nucleic acid can be isolated from members of the tribe *Phaseoleae*. In particular, the nucleic acid can be obtained from *Dolichos lab lab*, known as hyacinth beans and other common names throughout the world, from varieties of the common bean (*Phaseolus vulgaris*), e.g., red kidney beans, white kidney beans, etc., and from *Vigna sinensis*, commonly known as the black-eyed pea. In its native form isolated from such natural sources, the nucleic acid appears to encode a mannose/glucose-specific legume lectin. An exemplary isolation of the nucleic acid of the invention from *Dolichos lab lab* is described hereinbelow.

The entire gene or additional fragments of the gene are preferably isolated by using the known DNA sequence or a fragment thereof as a probe. To do so, restriction fragments from a genomic or cDNA library are identified by Southern hybridization using labeled oligonucleotide probes derived from SEQ ID NO:1.

DNA according to the invention can also be chemically synthesized by methods known in the art. For example, the DNA can be synthesized chemically from the four nucleotides in whole or in part by methods known in the art. Such methods include those described in Caruthers (1985). DNA can also be synthesized by preparing overlapping double-stranded oligonucleotides, filling in the gaps, and ligating the ends together. See, generally, Sambrook et al. (1989) and Glover et al. (1995).

DNA expressing functional homologs of the protein can be prepared from wild-type DNA by site-directed mutagenesis. See, for example, Zoller et al. (1982); Zoller (1983); and Zoller (1984); McPherson (1991).

The DNA obtained can be amplified by methods known in the art. One suitable method is the polymerase chain reaction (PCR) method described in Saiki et al. (1988), Mullis et al., U.S. Patent No. 4,683,195, and Sambrook et al. (1989). It is convenient to amplify the clones in the lambda-gt10 or lambda-gt11 vectors using lambda-gt10- or lambda-gt11-specific oligomers as the amplimers (available from Clontech, Palo Alto, CA).

Larger synthetic nucleic acid structures can also be manufactured having specific and recognizable utilities according to the invention. For example, vectors (e.g., recombinant expression vectors) are known which permit the incorporation of nucleic acids of interest for cloning and transformation of other cells. Thus, the invention further includes vectors (e.g., plasmids, phages, cosmids, etc.) which incorporate the nucleotide sequence of the invention,

especially vectors which include the gene for expression of the protein encoded by the nucleic acid of the invention.

The DNA of the invention can be replicated and used to express recombinant protein following insertion into a wide variety of host cells in a wide variety of cloning and expression vectors. The host can be prokaryotic or eukaryotic. The DNA can be obtained from natural sources and, optionally, modified. The genes can also be synthesized in whole or in part.

Cloning vectors can comprise segments of chromosomal, non-chromosomal and synthetic DNA sequences. Some suitable prokaryotic cloning vectors include plasmids from *E. coli*, such as colE1, pCR1, pBR322, pMB9, pUC, pKSM, and RP4. Prokaryotic vectors also include derivatives of phage DNA such as M13fd, and other filamentous single-stranded DNA phages.

Vectors for expressing proteins in bacteria, especially *E. coli*, are also known. Such vectors include the pK233 (or any of the *tac* family of plasmids), T7, and lambda P<sub>L</sub>. Examples of vectors that express fusion proteins are PATH vectors described in Dieckmann and Tzagoloff (1985). These vectors contain DNA sequences that encode anthranilate synthetase (TrpE) followed by a polylinker at the carboxy terminus. Other expression vector systems are based on beta-galactosidase (pEX); maltose binding protein (pMAL); glutathione S-transferase (pGST). See., e.g., Smith (1988) and Abath (1990).

Vectors useful for cloning and expression in yeast are available. A suitable example is the 2 $\mu$  circle plasmid.

Suitable cloning/expression vectors for use in mammalian cells are also known. Such vectors include well-known derivatives of SV-40, adenovirus, cytomegalovirus (CMV) retrovirus-derived DNA sequences. Any such vectors, when coupled with vectors derived from a combination of plasmids and phage DNA, i.e., shuttle vectors, allow for the isolation and identification of protein coding sequences in prokaryotes.

Further eukaryotic expression vectors are known in the art (e.g., Southern et al. (1982); Subramani et al. (1981); Kaufmann et al. (1982a); Kaufmann et al. (1982b); Scahill et al. (1983); Urlaub et al. (1980).

The expression vectors useful in the present invention contain at least one expression control sequence that is operatively linked to the DNA sequence or fragment to be expressed.



The control sequence is inserted in the vector in order to control and to regulate the expression of the cloned DNA sequence. Examples of useful expression control sequences are the *lac* system, the *trp* system, the *tac* system, the *trc* system, major operator and promoter regions of phage lambda, the control region of fd coat protein, the glycolytic promoters of yeast, e.g., the promoter for 3-phosphoglycerate kinase, the promoters of yeast acid phosphatase, e.g., Pho5, the promoters of the yeast alpha-mating factors, and promoters derived from polyoma, adenovirus, retrovirus, and simian virus, e.g., the early and late promoters or SV40, and other sequences known to control the expression of genes of prokaryotic or eukaryotic cells and their viruses or combinations thereof.

Useful expression hosts include well-known prokaryotic and eukaryotic cells. Some suitable prokaryotic hosts include, for example, *E. coli*, such as *E. coli* SG-936, *E. coli* HB101, *E. coli* W3110, *E. coli* X1776, *E. coli* X2282, *E. coli* DHI, and *E. coli* MRC1, *Pseudomonas*, *Bacillus*, such as *B. subtilis*, and *Streptomyces*. Suitable eukaryotic cells include yeasts and other fungi, insect, animal cells, such as COS cells and CHO cells, human cells and plant cells in tissue culture.

### Fusion Proteins

The protein can be expressed in the form of a fusion protein with an appropriate fusion partner. The fusion partner preferably facilitates purification and identification. Increased yields can be achieved when the fusion partner is expressed naturally in the host cell. Some useful fusion partners include beta-galactosidase (Gray et al. 1982); *trpE* (Itakura et al. 1977); protein A (Uhlen et al. 1983); glutathione S-transferase (Johnson 1989; Van Etten et al. 1989); and maltose binding protein (Guan et al. 1987; Maina et al. 1988; Riggs 1990).

Such fusion proteins can be purified by affinity chromatography using reagents that bind to the fusion partner. The reagent can be a specific ligand of the fusion partner or an antibody, preferably a monoclonal antibody. For example, fusion proteins containing beta-galactosidase can be purified by affinity chromatography using an anti-beta-galactosidase antibody column (Ullman 1984). Similarly, fusion proteins containing maltose binding protein can be purified by affinity chromatography using a column containing cross-linked amylose; see Guan, European Patent Application 286,239, incorporated herein by reference.

Optionally, the DNA that encodes the fusion protein is engineered so that the fusion protein contains a cleavable site between the protein and the fusion partner. The protein can occur at the amino-terminal or the carboxy-terminal side of the cleavage site. Both chemical and enzymatic cleavable sites are known in the art. Suitable examples of sites that are

5 cleavable enzymatically include sites that are specifically recognized and cleaved by collagenase (Keil et al. 1975); enterokinase (Hopp et al. 1988); factor Xa (Nagai et al. 1987); and thrombin (Eaton et al. 1986). Collagenase cleaves between proline and X in the sequence Pro-X-Gly-Pro wherein X is a neutral amino acid. Enterokinase cleaves after lysine in the sequence Asp-Asp-Asp-Asp-Lys. Factor Xa cleaves after arginine in the sequence Ile-Glu-

10 Gly-Arg. Thrombin cleaves between arginine and glycine in the sequence Arg-Gly-Ser-Pro.

Specific chemical cleavage agents are also known. For example, cyanogen bromide cleaves at methionine residues in proteins.

The recombinant protein is purified by methods known in the art. Such methods include affinity chromatography using specific antibodies. Alternatively, the recombinant

15 protein can be purified using a combination of ion-exchange, size-exclusion, and hydrophobic interaction chromatography using methods known in the art. These and other suitable methods are described, e.g., in Marston (1987, 1990).

Mixtures of proteins can be separated by, for example, SDS-PAGE in accordance with the method of Laemmli (1970). The molecular weights were determined by resolving single

20 bands on SDS-PAGE and comparing their positions to those of known standards. The method is understood by those in the art to be accurate within a range of 3-5%. Molecular weights can vary slightly between determinations.

### Fragments and Probes

As noted, the invention also includes fragments of the nucleic acid specified as

25 SEQ ID NO:1. Such fragments include primers and probes which are useful as tools in numerous molecular engineering techniques. The fragment can be used as a primer ("amplimer") to selectively amplify nucleic acid, such as genomic DNA, total RNA, etc. The fragment can also be an oligonucleotide complementary to a target nucleic acid molecule, i.e., the fragment can be a probe. In either case, the oligonucleotide can be RNA or DNA. The

30 length of the oligonucleotide is not critical, as long as it is capable of hybridizing to the target

molecule. The oligonucleotide should contain at least 6 nucleotides, preferably at least 10 nucleotides, and, more preferably, at least 15 nucleotides. There is no upper limit to the length of the oligonucleotide. Longer fragments are more difficult to prepare and require longer hybridization times. Therefore, the oligonucleotide should not be longer than necessary. Normally, the oligonucleotide will not contain more than 50 nucleotides, preferably not more than 40 nucleotides, and, more preferably, not more than 30 nucleotides.

Methods for determining whether a probe nucleic acid molecule recognizes a specific target nucleic acid molecule in a sample are known in the art. Generally, a labeled probe that is complementary to a nucleic acid sequence suspected of being in a sample is prepared.

Preferably, the target nucleic acid molecule is immobilized. The presence of probe hybridized to the target nucleic acid molecule indicates the presence of the nucleic acid molecule in the sample. Examples of suitable assay methods are described in Dallas et al. (1975); Grunstein et al. (1975); U.S. Patent No. 4,731,325, U.S. Patent No. 4,683,195, U.S. Patent No. 4,882,269, and PCT publication WO 90/01069, all of which are incorporated herein by reference.

The probes described above are labeled in accordance with methods known in the art. The label can be a radioactive atom, an enzyme, or a chromophoric moiety.

Methods for labeling oligonucleotide probes have been described, for example, in Leary et al. (1983); Renz et al. (1984); Richardson et al. (1983); Smith et al. (1985); and Meinkoth et al. (1984).

The label can be radioactive. Some examples of useful radioactive labels include  $^{32}\text{P}$ ,  $^{125}\text{I}$ ,  $^{131}\text{I}$ , and  $^3\text{H}$ . Use of radioactive labels have been described in U.K. patent document 2,034,323, and U.S. Patent Nos. 4,358,535, and 4,302,204, each incorporated herein by reference.

Some examples of non-radioactive labels include enzymes, chromophores, atoms and molecules detectable by electron microscopy, and metal ions detectable by their magnetic properties.

Some useful enzymatic labels include enzymes that cause a detectable change in a substrate. Some useful enzymes and their substrates include, for example, horseradish peroxidase (pyrogallol and o-phenylenediamine), beta-galactosidase (fluorescein beta-D-galactopyranoside), and alkaline phosphatase (5-bromo-4-chloro-3-indolyl phosphate/nitro

blue tetrazolium). The use of enzymatic labels have been described in U.K. 2,019,404, and EP 63,879, each incorporated herein by reference, and by Rotman (1961).

Useful chromophores include, for example, fluorescent, chemiluminescent, and bioluminescent molecules, as well as dyes. Some specific chromophores useful in the present invention include, for example, fluorescein, rhodamine, Texas red, phycoerythrin, umbelliferone, luminol.

The labels can be conjugated to the antibody or nucleotide probe by methods that are well known in the art. The labels can be directly attached through a functional group on the probe. The probe either contains or can be caused to contain such a functional group. Some examples of suitable functional groups include, for example, amino, carboxyl, sulfhydryl, maleimide, isocyanate, isothiocyanate.

Alternatively, labels such as enzymes and chromophoric molecules can be conjugated to the antibodies or nucleotides by means of coupling agents, such as dialdehydes, carbodiimides, dimaleimides, and the like.

The label can also be conjugated to the probe by means of a ligand attached to the probe by a method described above and a receptor for that ligand attached to the label. Any of the known ligand-receptor combinations is suitable. Some suitable ligand-receptor pairs include, for example, biotin-avidin or -streptavidin, and antibody-antigen. The biotin-avidin combination is preferred.

In any case, methods for making and using nucleic acid probes are well documented in the art. For example, see Keller et al. (1993) and Hames et al. (1995).

The following examples are provided to assist in a further understanding of the invention. The particular materials and conditions employed are intended to be further illustrative of the invention and are not limiting upon the reasonable scope thereof.

## EXAMPLE 1

### RNA Isolation and cDNA Synthesis

Total RNA was prepared from mid-maturation *Dolichos lab lab* seeds stored at -70°C following the procedure of Pawloski et al. (1994). Poly (A<sup>+</sup>) RNA was obtained from this total RNA using the PolyAtract mRNA Isolation System (Promega) according to the manufacturer's instructions. Avian myeloblastosis virus reverse transcriptase (Promega) was

used to generate cDNA from 0.5  $\mu\text{g}$  poly(A<sup>+</sup>)RNA, or from 3.0  $\mu\text{g}$  of total RNA, using 1  $\mu\text{g}$  of oligo(dT) in standard reaction conditions (Sambrook et al. 1989).

Polymerase Chain Reaction and cDNA Cloning**EXAMPLE 2A**

Based on the amino acid sequence published by Gowda et al. (1994), two degenerate oligonucleotide primers were designed using *Phaseolus* codon usage (Devereux et al. 1984):

5 MLA AA (AG) TT (TC) GA (TC) CC (AT) AA (TC) CA (AG) GA (AG) GA (SEQ ID NO:3)

MLZ TT (AT) CC (AG) TT (TC) TGCCA (AG) TCCCA (SEQ ID NO:4)

A 500+ bp product was amplified from cDNA prepared as described in Example 1, by 30 cycles of polymerase chain reaction (PCR), each cycle comprising 40 s at 94°C, 40 s at 50°C, 60 s at 72°C, followed by an extension step at 72°C for 10 min. Reactions were  
10 performed in 50 µL containing 30 pmol of each primer, 0.2 mM deoxyribonucleotides and 0.5 unit of AmpliTaq polymerase (Perkin Elmer) in the corresponding buffer.

The 500 bp product obtained by PCR was cloned in the cloning vector, pCR2.1 (Invitrogen), and sequenced by sequenase dideoxy chain termination (United States Biochemicals) using the following primers:

15 GTACCGAGCTCGGAT (SEQ ID NO:5)

TCTAGATGCATGCTCGAG (SEQ ID NO:6).

This sequence was designated "FRILa," as relating to the gene encoding the protein of interest, designated "FRIL" as noted above.

**EXAMPLE 2B**

20 Based on the sequence of the FRILa amplified product, a specific primer was prepared:

MLX GTTGGACGTCAATTCCGATGTG (SEQ ID NO:7)

A degenerate primer corresponding to the first five amino acids of the sequence published by Gowda et al. (1994) was also prepared:

25 MLI GC (TC) CA (AG) TC (TC) CT (TC) TC (TC) TT (SEQ ID NO:8)

The MLX and MLI primers were used in combination to amplify a 480 bp product from cDNA prepared as in Example 1, through 30 PCR cycles using the same conditions described above. This secondary amplified fragment was cloned in the pCR2.1 vector and sequenced as described above, and was designated "FRILb."

**EXAMPLE 2C**

The 3' end of *FRIL* was obtained through rapid amplification of cDNA ends by polymerase chain reaction (RACE-PCR) (see, e.g., Frohman 1990) using the 5'/3' RACEKIT (Boehringer Mannheim) according to the manufacturer's instructions. In the cDNA synthesis  
5 for the 3' RACE, an oligo(dT) anchor primer ("AP") supplied with the kit was used, at a concentration of 32.5  $\mu$ M, using the standard conditions described above in Example 1.

AP            GACCACGCGTATCGATGTCGAC            (SEQ ID NO:9)

Nested PCR amplifications were performed using the AP anchor primer in combination with a specific primer having the following sequence:

10    MLB            AAGTTAGACAGTGCAGGAAAC            (SEQ ID NO:10).

The amplification conditions were again 30 cycles of 40 s at 94°C, 40 s at 55°C, 60 s at 72°C each, with an extension step at 72°C for 10 min. A 900+ bp product was obtained, which was subcloned in pCR2.1 and sequenced as described above, and was designated "FRILc" (SEQ ID NO:1).

15    **EXAMPLE 2D**

To obtain the full length cDNA clone, the anchor primer AP was used in combination with a specific primer corresponding to the first 5 amino acids encoded at the 5'-terminus:

MLII            GCACAGTCATTGTCATTTAG            (SEQ ID NO:11).

The full length cDNA was obtained through 30 cycles of PCR, each cycle comprising 60 s at  
20    94°C, 60 s at 58°C, 90 s at 72°C, with an extension step at 72°C for 10 min. The reaction was performed in 100  $\mu$ L containing 30 pmol of each primer, 0.2 mM deoxyribonucleotide, 1.0 unit of Pfu polymerase (Stratagene). The MLII and AP primers were designed to generate an *Eco*RI site at each end (3' and 5') of the polynucleotide sequence. The full length cDNA was ligated into the *Eco*RI site of the cloning vector pCR2.1, resulting in the final product  
25    "pCR2.1-DLA" illustrated schematically in Figure 1.

**EXAMPLE 3**The Nucleotide Sequence of *FRIL*

The *FRIL*c clone obtained as described in Example 2C was sequenced completely using the dideoxy chain termination method. The nucleotide sequence of the full-length cDNA is:

5  
1 GCACAGTCAT TGTCAATTTAG TTTCACCAAG TTTGATCCTA ACCAAGAGGA  
51 TCTTATCTTC CAAGGTCATG CCACTTCTAC AAACAATGTC TTACAAGTCA  
101 CCAAGTTAGA CAGTGCAGGA AACCCCTGTGA GTTCTAGTGC GGGAAGAGTG  
151 TTATATTCTG CACCATTGCG CCTTTGGGAA GACTCTGCGG TATTGACAAG  
10 201 CTTTGACACC ATTATCAACT TTGAAATCTC AACACCTTAC ACTTCTCGTA  
251 TAGCTGATGG CTTGGCCTTC TTCATTGCAC CACCTGACTC TGTCATCAGT  
301 TATCATGGTG GTTTTCTTGG ACTCTTTCCC AACGCAAACA CTCTCAACAA  
351 CTCTTCCACC TCTGAAAACC AAACCACCAC TAAGGCTGCA TCAAGCAACG  
401 TTGTTGCTGT TGAATTTGAC ACCTATCTTA ATCCCGATTA TGGTGATCCA  
15 451 AACTACATAC ACATCGGAAT TGACGTCAAC TCTATTAGAT CCAAGGTAAC  
501 TGCTAAGTGG GACTGGCAAA ATGGGAAAAT AGCCACTGCA CACATTAGCT  
551 ATAACCTCTGT CTCTAAAAGA CTATCTGTTA CTAGTTATTA TGCTGGGAGT  
601 AAACCTGCGA CTCTCTCCTA TGATATTGAG TTACATACAG TGCTTCCTGA  
651 ATGGGTCAGA GTAGGGTTAT CTGCTTCAAC TGGACAAGAT AAAGAAAGAA  
20 701 ATACCGTTCA CTCATGGTCT TTCACTTCAA GCTTGTGGAC CAATGTGGCG  
751 AAGAAGGAGA ATGAAAACAA GTATATTACA AGAGGCGTTC TGTGATGATA  
801 TATGTGTATC AATGATTTTC TATGTTATAA GCATGTAATG TGCGATGAGT  
851 CAATAATCAC AAGTACAGTG TAGTACTTGT ATGTTGTTTG TGTAAGAGTC  
901 AGTTTGCTTT TAATAATAAC AAGTGCAGTT AGTACTTGT  
25 (SEQ ID NO:1)

The *FRIL* nucleotide sequence enabled inference of a derived amino acid sequence for the *FRIL* protein:

AQSLSFSFTK FDPNQEDLIF QGHATSTNNV LQVTKLDSAG NPVSSSAGRV  
LYSAPLRLWE DSAVLTSFDT IINFEISTPY TSRIADGLAF FIAPPDSVIS  
30 YHGGFLGLFP NANTLNNST SENQTTTKAA SSNVVAVEFD TYLNPDYGDP  
NYIHIGIDVN SIRSKVTAKW DWQNGKIATA HISYNSVSKR LSVTSYYAGS



KPATLSYDIE LHTVLPEWVR VGLSASTGQD KERNTVHSWS FTSSLWTNVA  
 KKENENKYIT RGVL

(SEQ ID NO:2)

A comparative illustration of the derived FRIL amino acid sequence with the reported amino acid sequence of the mannose lectin as determined by Gowda et al. (1994) is shown in Figure 2. The single sequence derived for FRIL protein comprises domains that correspond directly and with substantial homology to the  $\alpha$  subunit (SEQ ID NO:12) and  $\beta$  subunit (SEQ ID NO:13) of the protein described by Gowda et al. (1994). When the  $\beta$  subunit of the Gowda et al. protein is assigned to the N-terminal domain and is followed linearly by the  $\alpha$  subunit, the arrangement of the polypeptides shows homology to other legume lectins. However, the derived FRIL amino acid sequence comprises an insert of seven amino acid residues (aa27-34) that does not occur in the protein described by Gowda et al. Several other differences between the amino acid sequences of the two proteins are also readily discernible from Figure 2.

#### EXAMPLE 4

##### Site-Specific Mutagenesis

To establish functionality of homologs of the protein encoded by the FRIL cDNA, a mutation was made in the FRIL cDNA clone. The domains of the derived protein and the pea lectin that include the mutation site are shown below:

FRIL . Y L N P D Y G . D P N Y I H I G I D V (SEQ ID NO:14)  
 Pea F Y . N A A W D P S N R D R H I G I D V (SEQ ID NO:15)

It is known that the asparagine residue (the highlighted "N") in the pea lectin is involved in binding to its saccharide ligand. The corresponding asparagine in FRIL (position 141 of the amino acid sequence, based on the sequence including the 15 amino acid signal peptide) was mutated to aspartic acid ("D"). This mutation was designated "N141D" for convenience.

To introduce the mutation, recombinant PCR was performed (Higuchi 1990). Two PCR reactions were carried out separately on the full length cDNA using two primers that contain the same mutation and produce two products with an overlapping region:

MutI CCATAATCGGGATCAAGATAGGTG (SEQ ID NO:16)

MutII CACCTATCTTGATCCCGATTATGG (SEQ ID NO:17)

The primary PCR products were purified with the QIAquick PCR Purification kit (QIAGEN), according to the manufacturer's instructions. The overlapping primary products were then combined and amplified together in a single second reaction using flanking primers:

M1 Forw      AACTCAGCCGCACAGTCATTGTCA      (SEQ ID NO:18)

5      APEcoRI      GAATTCGACCACGCGTATCGATGTCGAC      (SEQ ID NO:19)

Both the primary and the secondary PCR reactions were performed in 100  $\mu$ L containing 50 pmol of each primer, 0.4 mM deoxyribonucleotide and 1.0 unit Pfu polymerase (Stratagene) in the corresponding buffer. The primary PCR reaction amplified the two separate fragments in 30 cycles, each cycle comprising 40 s at 94°C, 40 s at 50°C, 72°C 60 s, with an extension step at 72°C for 10 min. The second PCR reaction amplified the recombinant fragment in 12 cycles using the same conditions reported above.

The resulting full-length fragment contained the mutation. The recombinant mutated product was cloned in the *Eco*RI site of the cloning vector pCR2.1, as illustrated schematically in Figure 3, and sequenced as described above. This plasmid is referred to as "pCR2.1-DLA(D)." 15

## EXAMPLE 5

### Construction of Plant Expression Vectors and *Nicotiana tabacum* Transformation

Recombinant PCR was used to modify the 5' ends of both the wild-type and the mutant FRIL clones, to introduce a signal peptide for entry of the protein into the endoplasmic reticulum. Following the procedure of Higuchi (1990), the sequence encoding the signal peptide and the full-length cDNA clones were amplified in two separate primary PCR reactions. The signal peptide sequence was obtained from the amplification of the binary vector pTA4, harboring the complete sequence of the  $\alpha$ -amylase inhibitor gene (Hoffman et al. 1982; Moreno et al. 1989).

25      The following primers were used for amplification of the signal peptide sequence:

Sigforw      GAATTCATGGCTTCCTCCAAC      (SEQ ID NO:20)

Sigrev      TGA CTGTGCGGCTGAGTTTGCGTGGGTG      (SEQ ID NO:21)

The primers M1Forw (SEQ ID NO:18) and APEcoRI (SEQ ID NO:19) used for amplification of the FRIL cDNA in Example 4 above, were again used to amplify the FRIL cDNA. 30

The primers used for the secondary reactions were Sigforw and APEcoRI, which were designed to generate *EcoRI* sites at the 5' and the 3' ends. Both the primary and the secondary PCR reactions were performed as discussed above for the site-directed mutagenesis.

5 The wild-type recombinant product SpDLA was cloned in the *EcoRI* site of the pBluescript SK+ cloning vector (Stratagene) to give the vector pBS-SpDLA, as shown in Figure 4. The mutant SpDLA(D) was cloned in the same site of the cloning vector pCR2.1 to give the vector pCR2.1-SpM1, as shown in Figure 5. The nucleotide sequence of each PCR product was determined as described above to verify the correct attachment of the signal peptide. The nucleotide sequence of SpDLA is defined by SEQ ID NO:22, and the derived amino acid sequence is defined by SEQ ID NO:23.

#### EXAMPLE 6

A binary vector was constructed for seed-specific expression of FRIL. For seed expression, the vicilin promoter obtained from the pCW66 (Higgins et al. 1988) was cloned 15 in *EcoRI/KpnI* sites of the plant expression vector pBIN19, to form pBINVicPro, as illustrated in Figure 6. Downstream of the vicilin promoter, the SpDLA cDNA sequence was ligated into the *EcoRI/SacI* site giving rise to the pBINVicPro-SpDLA, which is illustrated in Figure 7. The mutated cDNA clone SpDLA(D) was ligated in *EcoRI* site of the pBINVicPro vector to yield pBINVicPro-SpDLA(D), which is illustrated in Figure 8. No additional 20 termination sequences were added, relying instead on the stop codons and the polyadenylation site of the DLA and DLA(D) cDNA clones. Both vectors were transferred into *Agrobacterium tumefaciens* strain LBA4404 according to the freeze-thaw procedure reported by An et al. (1988).

25 *Agrobacterium*-mediated transformation of *Nicotiana tabacum* leaf disks was carried out and assayed as described (Horsch et al. 1985) using LBA4404 harboring the seed-specific expression vector pBINVicPro-SpDLA (Figure 9). Kanamycin-resistant plants (resistance being conferred by transformation with the pBIN19-based vectors that carry the gene) were scored for their ability to form roots in two consecutive steps of propagation in Murashige-Skoog medium containing 3% of sucrose and kanamycin sulfate (Sigma) 100 mg/mL.

**EXAMPLE 7****Expression of Recombinant FRIL in *E. coli***

The FRIL wild-type cDNA and mutant clones (without signal peptides), were ligated into the *EcoRI/SalI* and *EcoRI/XhoI* of the expression vector pGEX 4T-1 (Pharmacia), to form the expression constructs pGEX-M1 and pGEX M1(D), respectively illustrated in Figures 9 and 10. The host *E. coli* strain, BL21(D3), was purchased from Novagen, and transformed with the above construct using the calcium chloride method (see Sambrook et al. 1989; Gelvin et al. 1988; Altabella et al. 1990; and Pueyo et al. 1995). The induction of the tac promoter (Ptac) was achieved by adding IPTG (isopropyl- $\beta$ -D-thiogalactopyranoside) (Sigma) at a 1.0 mM final concentration when the cells reached an optical density of 0.4 - 0.6 at 600 nm. The cultures were allowed to grow for 12 h at 37°C after the addition of IPTG. Control non-induced cultures were maintained under similar conditions. The cells were lysed by treatment with 4 mg/mL lysozyme in phosphate-buffered saline containing 1% TRITON® X-100.

Total cellular protein was extracted from transformed *E. coli* cells and analyzed on SDS-PAGE on a 15% gel using a standard procedure (Sambrook et al. 1989). The cells from 1 mL of *E. coli* culture were suspended in the same volume of loading buffer (50 mM Tris HCl pH 6.8, 100 mM DTT, 2% SDS, 10% glycerol, 0.1% bromophenol blue) and vortexed. Following transfer to a nitrocellulose membrane, protein was stained with Coomassie Brilliant Blue R250. A representative separation is shown in Figure 11, with the lanes identified in Table 1, below.

**TABLE 1**  
Key to Figure 11

Lane No.	Content
1	Molecular Mass Marker (Bio-Rad)
2	Total Protein Extract from Non-Induced BL21(D3) pGEX-M1
3	Total Protein Extract from Induced BL21(D3) pGEX-M1
4	Total Protein Extract from Non-Induced BL21(D3) pGEX-M1(D)
5	Total Protein Extract from Induced BL21(D3) pGEX-M1(D)

The separation of proteins in Figure 11 shows that the induced cells ((lanes 3, 5) both produced an abundant polypeptide having a molecular mass of about 60 kDa (indicated by

arrow). The non-induced cells failed to produce any significant amount of this protein (lanes 2, 4).

## EXAMPLE 8

### Purification of Recombinant FRIL

5 Induced *E. coli* cells (200 mL) as described in Example 7 were harvested after 12 h induction at 37°C by centrifugation at 5000 g for 10 min. The pellet was washed with 50 mM Tris-HCl pH 8.0, 2 mM EDTA, and resuspended in 1/10 vol of 1% TRITON surfactant in TBS (20 mM Tris pH 7.5, 500 mM NaCl). The cells were lysed by adding 4 mg/mL of lysozyme and incubating at room temperature for 30-60 min. After  
10 centrifugation at 5000 g, the supernatant containing the total soluble proteins was discarded and the resulting pellet, comprising the inclusion bodies and containing the accumulated the recombinant fusion protein, was extracted with 8 M guanidine-HCl (Marston et al. 1993).

The recombinant fusion protein solubilized by guanidine-HCl was purified on  
15 GST-Sepharose beads (Pharmacia) according the manufacturer's instructions and eluted in 1 mL of reduced glutathione (Sigma). Samples of the purified fusion proteins were cleaved with thrombin (Novagen) using 5 cleavage units/mL purified fusion protein.

For immunoblot analysis (western blot), the purified proteins were separated by SDS-PAGE in general accordance with the method described in Example 7. The gel was equilibrated in transfer buffer (25 mM Tris pH 8.3, 192 mM Glycine, 20% MeOH) and  
20 blotted onto nitrocellulose (Bio-Rad) for 1 h at 100 V using a Bio-Rad electrotransfer apparatus. Non-specific binding was blocked by incubating the blots for at least 1 h in 1X TBS (20 mM Tris pH 7.5, 500 mM NaCl) containing 3% gelatin. Blotting was followed by incubation with a primary antibody (a polyclonal rabbit serum raised against the N-terminal peptide of the  $\beta$ -subunit of the *Phaseolus vulgaris* homolog of FRIL, 1:100 dilution, 3 h),  
25 followed by incubation with a secondary antibody (goat anti-rabbit IgG conjugated to horseradish peroxidase at 1:1000 dilution for 1 h). The blots were washed and the color developed with the color development reagent (Bio-Rad). A representative result is shown in Figure 12, with the lanes identified in Table 2, below.

**TABLE 2**  
Key to Figure 12

	Lane No.	Content
5	1	Purified Fusion Protein M1
	2	Purified Fusion Protein M1(D)
	3	Control
	4	Purified Fusion Protein M1 After Cleavage with Thrombin
10	5	Purified Fusion Protein M1(D) After Cleavage with Thrombin
	6	Control

The separation shown in Figure 12 demonstrates that the two forms of fusion protein have similar molecular masses of about 60 kDa, and that thrombin cleaved both types of fusion protein to produce a new polypeptide of molecular mass 30 kDa.

#### EXAMPLE 9

##### Recombinant FRIL Specifically Stimulates Proliferation of 3T3 Cells expressing the FLK2/FLT3 Receptor

The recombinant protein interacts with the mammalian FLK2/FLT3 tyrosine kinase receptor. A specific and quantitative biological assay using NIH 3T3 fibroblasts transfected either with a chimeric receptor having the extracellular portion of the murine FLK2/FLT3 receptor combined with the intracellular portion of the human Fms receptor (Dosil et al. 1993) or with the full length human receptor (Small et al. 1994) can be used to evaluate lectin biological activity during purification. Serial two-fold dilutions of lectin samples across rows of a 96 well plate allowed for greater than a thousand-fold range to access FLK2/FLT3 3T3 biological activity. Either the murine or human FLK2/FLT3 ligand (FL) (Lyman et al. 1993; Hannum et al. 1994) or the recombinant protein encoded by the nucleic acid of the invention rescues FLK2/FLT3-transfected cells from death in this assay.

Specifically, 3T3 cells cultured in tissue culture plates (Becton Dickinson Labware, Lincoln Park, New Jersey) are removed from the plates by washing cells twice in Hank's buffered saline solution (HBSS; Gibco Laboratories, Grand Island, NY). Non-enzymatic cell dissociation buffer (Gibco) is added for 15 minutes at room temperature. The resulting cells are washed in medium. FLK2/FLT3 3T3 cells are cultured at a final concentration of 3,000 cells per well in a volume of 100  $\mu$ L of serum-defined medium containing 10 mg/mL

rhIL1- $\alpha$ , 10% AIMV (Gibco) and 90% Dulbecco's modification of Eagle's medium (DMEM; Gibco) in 96 well plates. Under these assay conditions, cells die after two to four days of culture in a humidified incubator at 37°C and 5% CO<sub>2</sub> unless exogenously added ligand rescues cells from death. Each 96 well plate contains calf serum, which stimulates all 3T3 cells, as a positive control and medium only as a negative control ("blank"). Full-length Fms-transfected 3T3 cells (biological response shown in Tessler et al. 1994) serve as receptor-transfected control target cells, and parent 3T3 cells serve as untransfected control cells. Proliferation and cell survival is quantitated by addition of XTT (Diagnostic Chemicals Ltd, Charlottetown, Prince Edward Island, Canada), which is a tetraformazan salt cleaved by actively respiring cells (Roehm et al. 1991), quantitated spectrophotometrically using a Vmax kinetic plate reader (Molecular Devices Corp., Mountain View, CA), and recorded as either relative activity (units/mL) or as specific activity (units/mg). One unit of biological activity is defined as the reciprocal dilution at which half-maximal stimulation of cells is detected.

The crude protein extract from the *E. coli* cultures described in Example 7, above, was tested to determine whether expressed recFRIL possessed any capacity to stimulate FLK2/FLT3 3T3 cells using this assay. The data from this experiment are summarized in Figures 13A and 13B. Specifically, Figure 13A is a graph showing that the crude extract of the *E. coli* culture containing expressed FRIL specifically stimulates hFLK2/FLT3 cells; Figure 13B is a graph showing that the same extract does not stimulate untransfected 3T3 cells. In Figures 13A and 13B, medium control is represented by a solid line. The ordinate (absorbance) indicates cell viability measured by XTT at three days; the abscissa shows the reciprocal dilution of the extract sample. The apparent inhibition of proliferation observed at higher concentrations (Figure 13A) is not understood, but may relate to toxic components in the crude *E. coli* extract or the consequences of dose-related preservation of the 3T3 fibroblasts.

## EXAMPLE 10

### Recombinant FRIL Preserves Mononuclear Cells and Progenitors in Liquid Culture

The recFRIL protein preserves functional progenitors for at least two weeks in liquid culture. Figures 14A and 14B illustrate the results of an experiment in which recFRIL is shown to act in a dose-responsive manner to preserve human cord blood progenitors.

Figures 14A and 14B show that recombinant FRIL preserves cord blood mononuclear cells and progenitors in a dose-responsive manner in liquid culture. Cord blood mononuclear cells obtained by FICOLL-PAQUE® separation (Pharmacia Biotech, Piscataway, NJ) were cultured in serum-free medium (X-VIVO 10, BioWhittaker, Walkersville, MD) at a concentration of 200,000 cells/mL in a volume of 4 mL for two weeks without medium changes. Harvested cells were pelleted and resuspended in X-VIVO 10 before determining viable cell number by trypan blue (GIBCO, Grand Island, NY) exclusion. These results are shown in Figure 14A. The progenitor number and capacity of harvested cells were assessed by plating the cells in complete serum-free, methylcellulose colony assay medium (StemCell Technologies, Vancouver, BC, Canada). After two weeks, the resultant colonies were scored and the results are shown in Figure 14B. In Figures 14A and 14B, "blast" refers to colonies consisting of primitive, morphologically undifferentiated cells; "mix" refers to colonies consisting of myeloid and erythroid cells; "erythroid" refers to colonies consisting of erythroid cells; and "myeloid" refers to colonies consisting of myeloid cells. Cell number is shown on the ordinate; the abscissa shows the reciprocal dilution of the sample.

To assess whether recFRIL acts directly or indirectly through accessory cells to preserve progenitor cells, cord blood mononuclear cells were first enriched for progenitors expressing the CD34 antigen by immunomagnetic bead isolation (DynaL Corp., Lake Success, NY). Five hundred CD34<sup>+</sup> cells were placed into wells containing 100  $\mu$ L of serum-free medium (BIT9500, StemCell Technologies) either in the presence of recFL (PeproTech, Princeton, NJ) or a cytokine cocktail of rhIL3 + rhIL6 + rhIL11 + rhTpo + FL (BioSource International, Camarillo, CA) in 96-well plates and cultured for four weeks without medium changes. The numbers of functional progenitors from these cultures were assessed by plating cells in complete serum-free methylcellulose colony assay medium (StemCell Technologies). After two weeks, the resultant colonies were scored and the results are shown in Figure 15 (solid bars = recFRIL; open bars = cytokine cocktail). Clearly, progenitors were preserved only in the recFRIL-containing cultures. Thus, purified recFRIL acts directly on primitive hematopoietic progenitors.

Thus, while there have been described what are presently believed to be the preferred embodiments of the present invention, those skilled in the art will realize that other and further embodiments can be made without departing from the spirit of the invention, and it is



intended to include all such further modifications and changes as come within the true scope of the claims set forth herein.

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5 Zoller MJ, *DNA* 3(6):479-488 (1984).

**WHAT IS CLAIMED IS:**

1. An isolated nucleic acid molecule comprising a sequence that encodes a protein comprising an amino acid sequence as defined by SEQ ID NO:2, a homolog thereof, or a fragment thereof that contains the sequence TNNVLQVT.
2. A isolated nucleic acid molecule according to Claim 1, comprising a nucleotide sequence as defined by SEQ ID NO:1, a homolog thereof, or a unique fragment thereof.
3. An isolated nucleic acid molecule that encodes a protein that preserves progenitor cells, wherein the nucleic acid is isolated from a legume.
4. An isolated nucleic acid according to Claim 3, wherein the encoded protein comprises an amino acid sequence as defined by SEQ ID NO:2 or a fragment thereof that contains the sequence TNNVLQVT.
5. An isolated nucleic acid according to Claim 3, wherein the nucleic acid encodes a mannose/glucose-specific legume lectin.
6. An isolated nucleic acid according to Claim 3, wherein the nucleic acid is isolated from a legume from the tribe Phaseoleae.
7. An isolated nucleic acid according to Claim 7, wherein the nucleic acid is isolated from red kidney beans, white kidney beans, hyacinth beans, or black-eyed peas.
8. An isolated nucleic acid according to Claim 3, wherein the nucleic acid comprises a nucleotide sequence as defined by SEQ ID NO:1 or a unique fragment thereof.
9. An isolated nucleic acid according to Claim 3, wherein the encoded protein preserves progenitor cells that are at least unipotent progenitor cells.



10. An isolated nucleic acid according to Claim 3, wherein the encoded protein preserves progenitor cells that are pluripotent progenitor cells.
11. An isolated nucleic acid according to Claim 3, wherein the encoded protein preserves progenitor cells that are totipotent progenitor cells.
12. An isolated nucleic acid according to Claim 3, wherein the encoded protein preserves progenitor cells that are hematopoietic progenitor cells.
13. An isolated nucleic acid according to Claim 3, wherein the encoded protein preserves progenitor cells that comprise nerve, muscle, skin, gut, bone, kidney, liver, pancreas, or thymus progenitor cells.
14. An isolated nucleic acid according to Claim 9, wherein the encoded protein preserves progenitor cells that express the CD34 antigen.
15. An isolated nucleic acid according to Claim 9, wherein the encoded protein preserves progenitor cells that express the FLK2/FLT3 receptor.
16. An isolated nucleic acid according to Claim 15, wherein the encoded protein preserves progenitor cells that are cells modified to express FLK2/FLT3 receptors on their surface.
17. An isolated nucleic acid according to Claim 16, wherein the encoded protein has significant binding affinity for FLK2/FLT3 receptor on the cells, wherein binding of the encoded protein with the FLK2/FLT3 receptor mediates the inhibition of differentiation of the cells.
18. A method for preserving progenitor cells, comprising contacting progenitor cells with a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined

by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, in an amount sufficient to preserve the progenitor cells.

19. A method according to Claim 18, wherein the progenitor cells comprise hematopoietic progenitor cells.

20. A method according to Claim 19, wherein the progenitor cells comprise human cells that express the CD34 antigen and/or the FLK2/FLT3 receptor.

21. A method according to Claim 19, wherein the progenitor cells comprise murine cells that express the Sca antigen but that do not express mature blood cell lineage antigens.

22. A method according to Claim 18, wherein the method comprises contacting the progenitor cells with the protein *in vitro*, *ex vivo*, or *in vivo*.

23. A method according to Claim 18, wherein the method further comprises contacting the progenitor cells with FLK2/FLT3 ligand in an amount sufficient to selectively expand the number of progenitor cells without inducing differentiation thereof.

24. A method of treating a mammal in need of hematopoietic therapy, comprising:

a) obtaining a tissue sample from the mammal, the tissue sample comprising hematopoietic progenitor cells;

5 b) culturing the progenitor cells in the presence of a protein that preserves the progenitor cells, to provide cultured cells enriched in the progenitor cells, wherein the protein is encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT;

c) subjecting the mammal to conditions sufficient to effect myeloablation; and

10 d) administering the cultured cells to the mammal following the myeloablation to reconstitute the hematopoietic system of the mammal.

25. A method according to Claim 24, wherein the myeloablation conditions comprise bone marrow irradiation, whole body irradiation, or chemically-induced myeloablation.

26. A method of enriching progenitor cells, comprising culturing progenitor cells in a progenitor-preserving amount of a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT, wherein the protein specifically preserves the progenitor cells, and wherein the culturing is performed under conditions permitting preservation of progenitor cells while permitting the number of differentiated cells to decrease.

27. A method according to Claim 26, wherein the progenitor cells include primitive progenitor cells.

28. A method according to Claim 26, wherein the progenitor cells include mature progenitor cells.

29. A method according to Claim 26, wherein the progenitor cells are at least substantially free of stromal cells.

30. A method according to Claim 26, wherein the culturing conditions include culturing in a medium containing a cytotoxic agent that exhibits selective toxicity for proliferating cells.

31. A method according to Claim 30, wherein the cytotoxic agent is adriamycin, cyclophosphamide, taxol or other taxane, cisplatin, or 5-fluorouracil.

32. A method of improving hematopoietic competence in a mammal, comprising:  
a) culturing a tissue sample comprising hematopoietic progenitor cells in a growth medium containing a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an

5 amino acid sequence TNNVLQVT, in an amount sufficient to preserve the progenitor cells and to provide cultured cells enriched in the progenitor cells; and

b) transfusing the enriched cultured cells to the mammal to provide progenitor cells for generating blood cellular components in the mammal.

33. A method according to Claim 32, wherein the tissue sample comprises peripheral blood, umbilical cord blood, placental blood, or bone marrow.

34. A method according to Claim 33, wherein the tissue sample is autologous to the mammal.

35. A method according to Claim 32, wherein the tissue sample is at least substantially free of stromal cells.

36. A method according to Claim 32, further comprising ablating hematopoietic tissues in the mammal prior to the transfusing.

37. In a method of transfecting an exogenous DNA sequence into somatic cells, the improvement comprising transfecting progenitor cells selectively preserved by a protein encoded by an isolated nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence  
5 TNNVLQVT.

38. A composition for preserving viability of progenitor cells *ex vivo*, comprising a cell growth medium and a protein that preserves progenitor cells, wherein the protein is encoded by a nucleic acid comprising a nucleotide sequence defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino acid sequence TNNVLQVT.

39. A method for preserving progenitor cells in a mammal, comprising:

a) administering to the mammal a protein that specifically preserves progenitor cells, the protein being encoded by an isolated nucleic acid comprising a nucleotide sequence

defined by SEQ ID NO:1, a homolog thereof, or a fragment thereof that encodes an amino  
5 acid sequence TNNVLQVT, in an amount sufficient to preserve progenitor cells of the  
mammal in a substantially non-proliferative state;

b) exposing the mammal to myeloablative conditions sufficient to effect ablation of  
proliferating myeloid cells but sparing non-proliferating progenitor cells; and

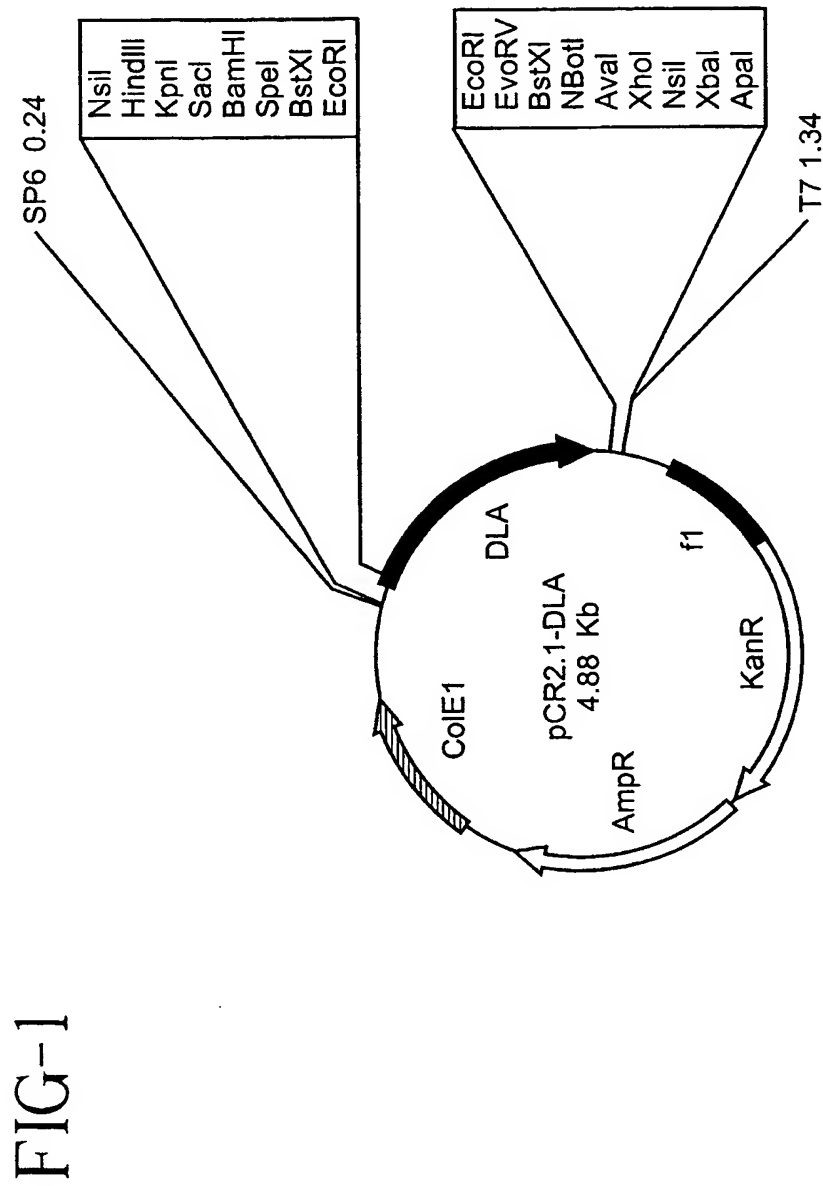
c) following the exposing, reestablishing proliferation or differentiation of the  
10 preserved progenitor cells.

40. A method according to Claim 39, wherein the reestablishing comprises  
administering to the mammal a cytokine in an amount sufficient to improve the viability of  
the progenitor cells

41. A method according to Claim 40, wherein the viability-improving cytokine is  
IL-1, IL-3, IL-6, IL-11, KL, or a combination thereof.

42. A method according to Claim 39, wherein the reestablishing comprises  
administering to the mammal a proliferation-stimulating amount of the FLK2/FLT3 ligand.

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2/15

## FIG-2

 $\beta$ -Subunit

Gowda 1 A Q S L S F S F T K F D P N Q E D L I F Q G T A T S . . . . . K L D S A G N P V S S S A G R V 42  
 FRIL 1 A Q S L S F S F T K F D P N Q E D L I F Q G H A T S T N N V L Q V T K L D S A G N P V S S S A G R V 50

43 L Y S A P L R L W E D S A V L T S F D P T I Y . . I F T N Y T S R I A D G L A . F I A P P D S V I S 89  
 51 L Y S A P L R L W E D S A V L T S F D T I I N F E I S T P Y T S R I A D G L A F I A P P D S V I S 100

90 Y H G G F L G L F P N A A E S G . . . . . 105  
 101 Y H G G F L G L F P N A N T L N S S T S E N 123

 $\alpha$ -Subunit

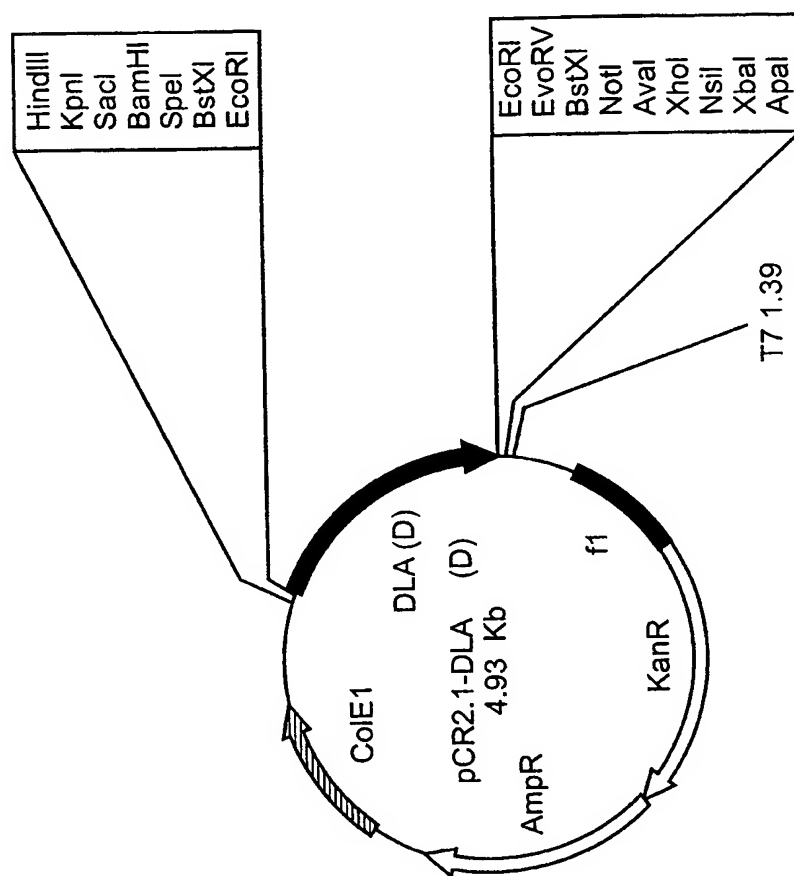
Gowda 1 . . . . . I A E S N V V A V E F D T D Y L N P D Y G D P N Y I H I G I D V N S I R S K V T A S W D W 45  
 FRIL 1 Q T T T K A A S S N V V A V E F D T . Y L N P D Y G D P N Y I H I G I D V N S I R S K V T A K W D W 49

46 Q N G K I A T A H I S Y N S V S K R L S V T T Y Y P G R G K P A T S Y D I E L H T V L P E W V R V G 95  
 50 Q N G K I A T A H I S Y N S V S K R L S V T S Y A G S K P A T L S Y D I E L H T V L P E W V R V G 99

96 L S A S T G Q N I E R N T V H S W S F T S S L W T N V A K V G V A S I S G . . . . . 132  
 100 L S A S T G Q D K E R N T V H S W S F T S S L W T N V A K K E N E N K Y I T R G V L \* Y M C I N D 149

3/15

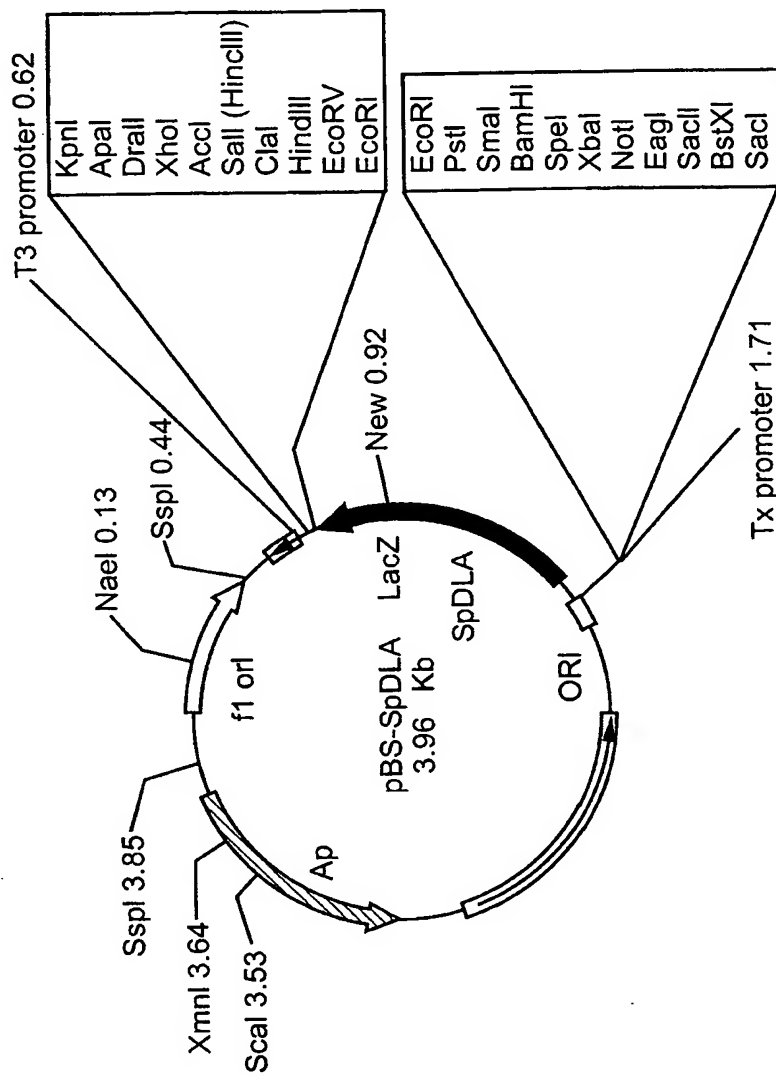
FIG-3





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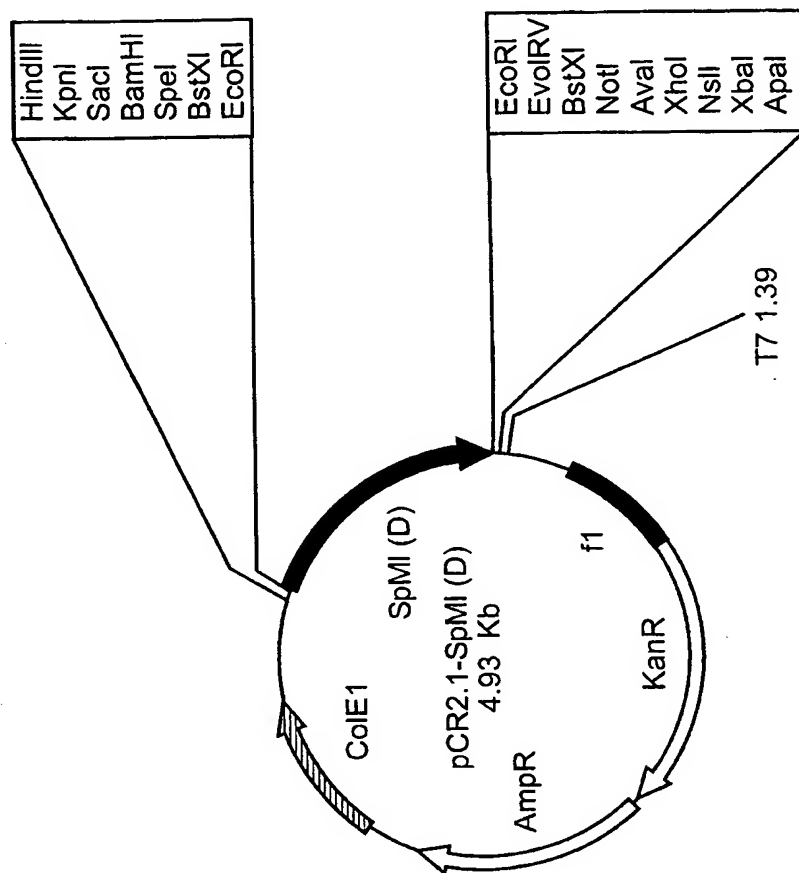
FIG-4



SUBSTITUTE SHEET (RULE 26)

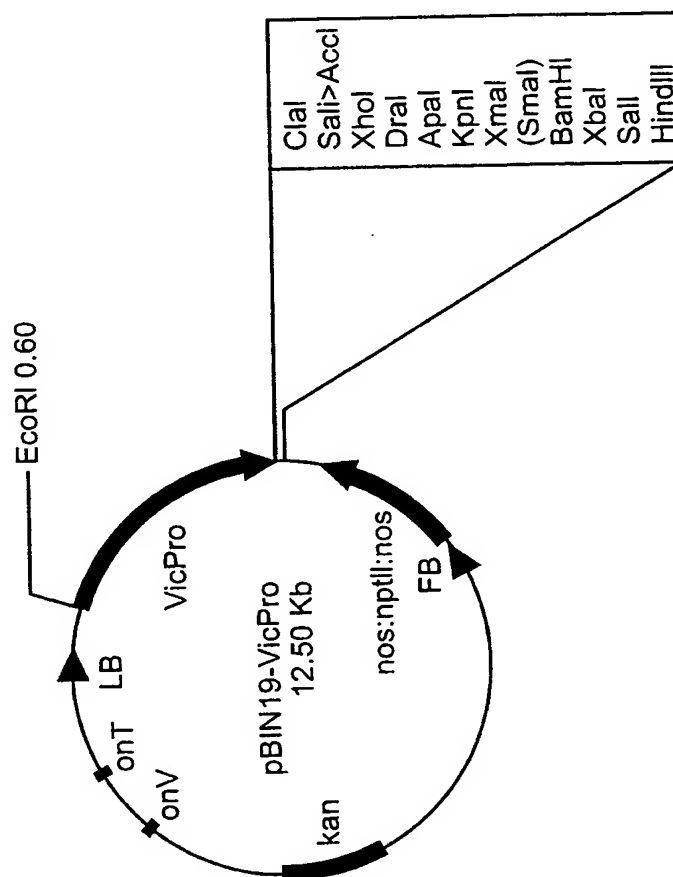
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FIG-5



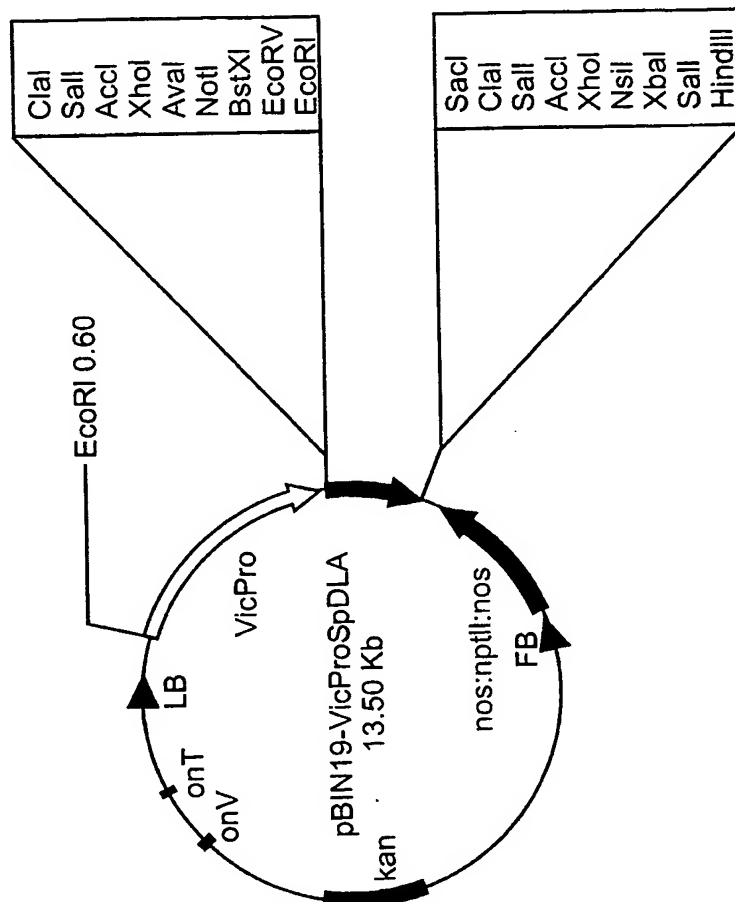
6/15

FIG-6



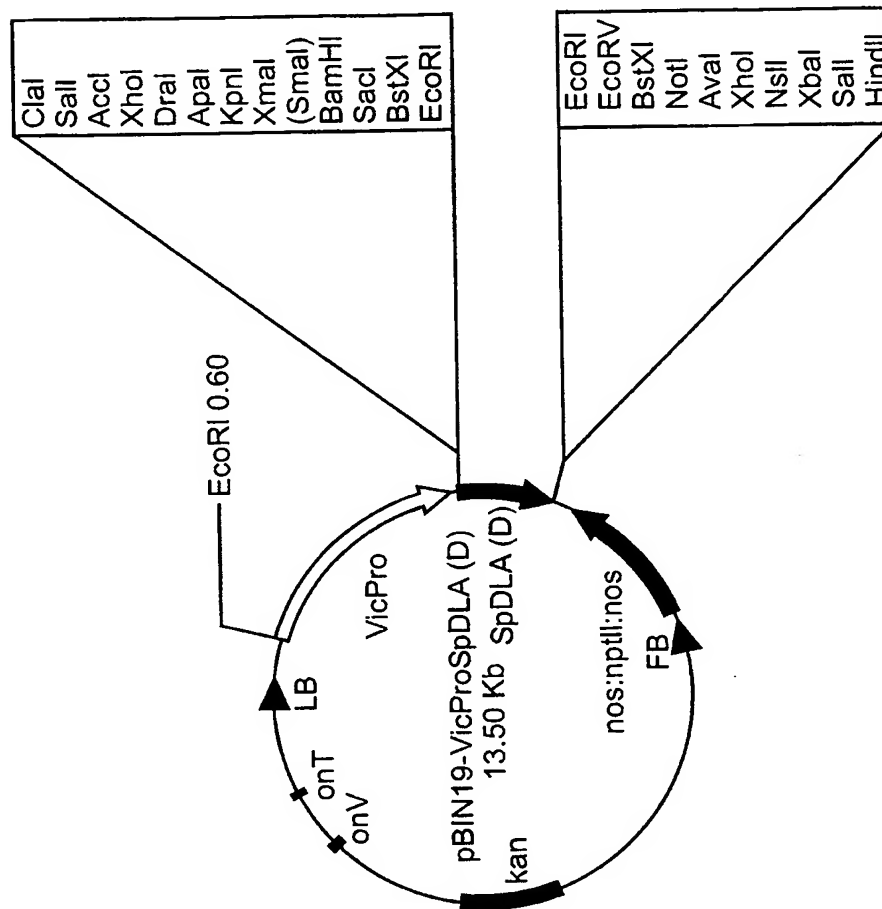
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FIG-7



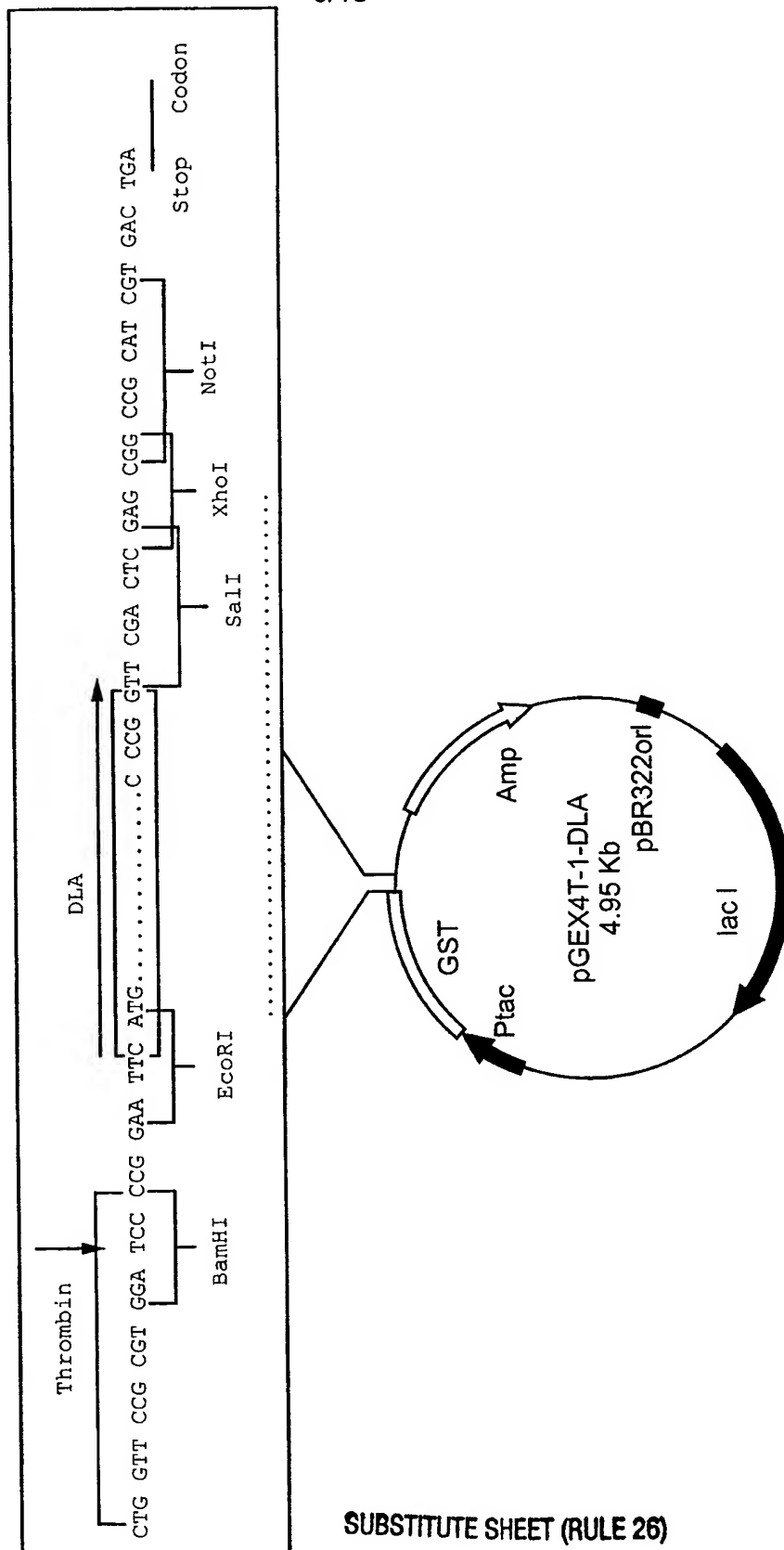
8/15

FIG-8



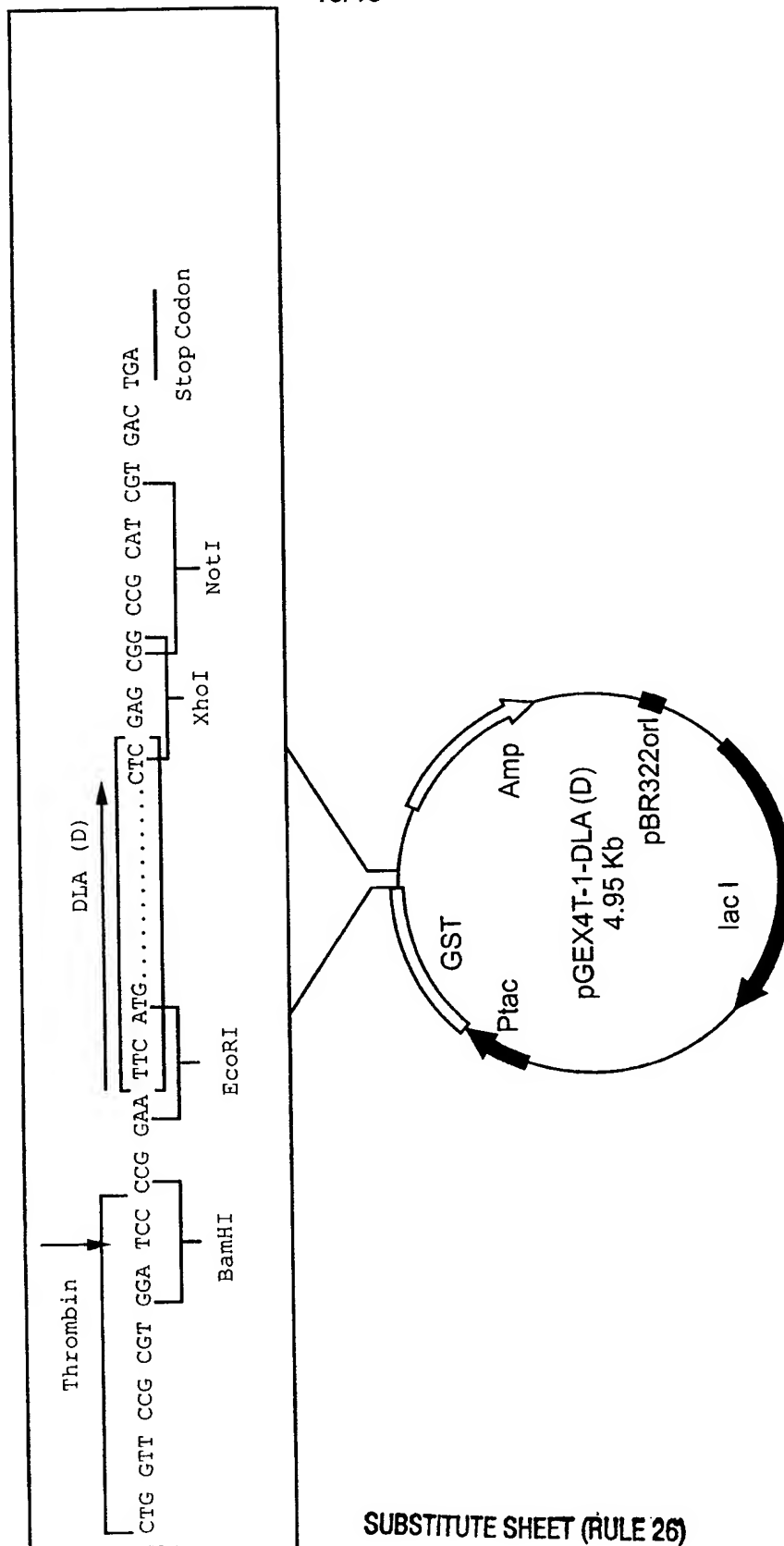
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FIG-9



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FIG-10



SUBSTITUTE SHEET (RULE 26)

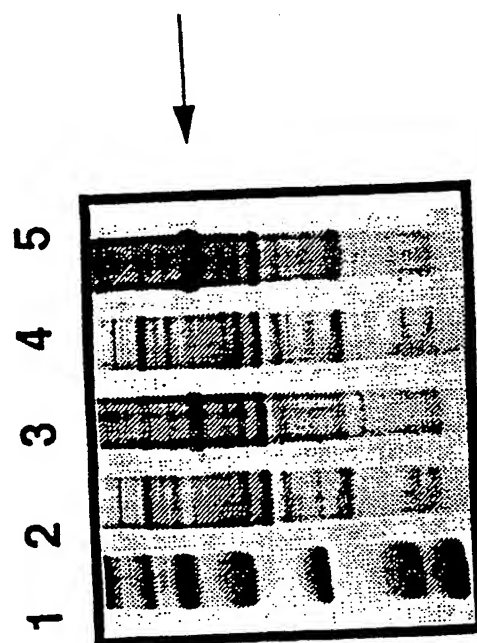


FIGURE 11



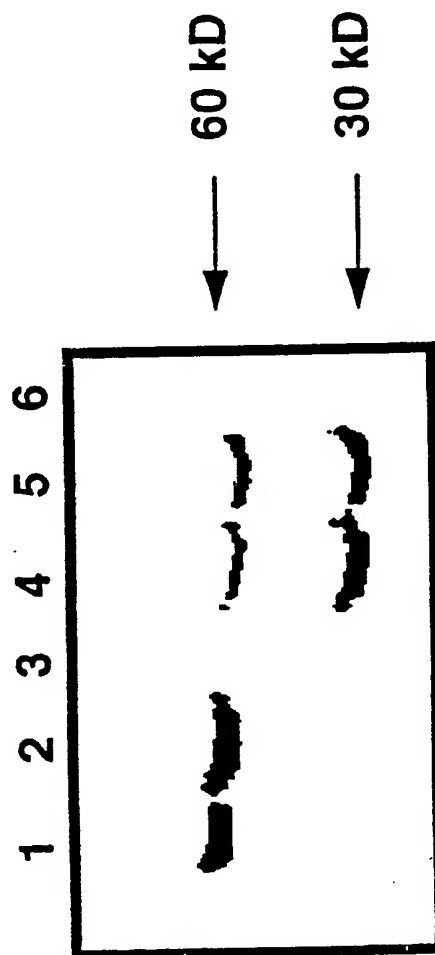
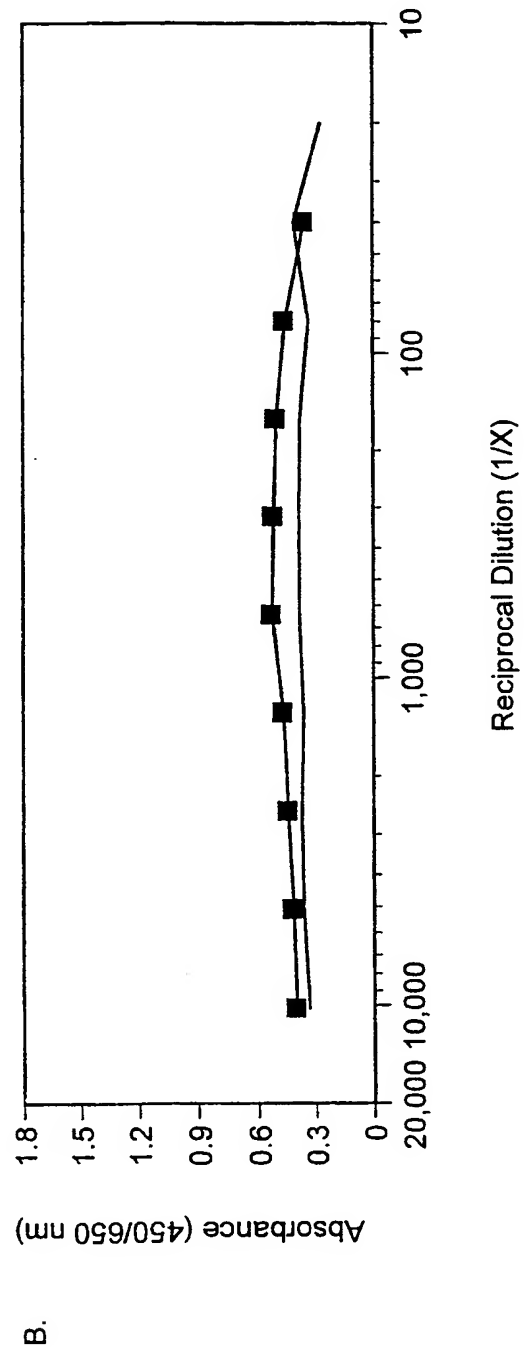
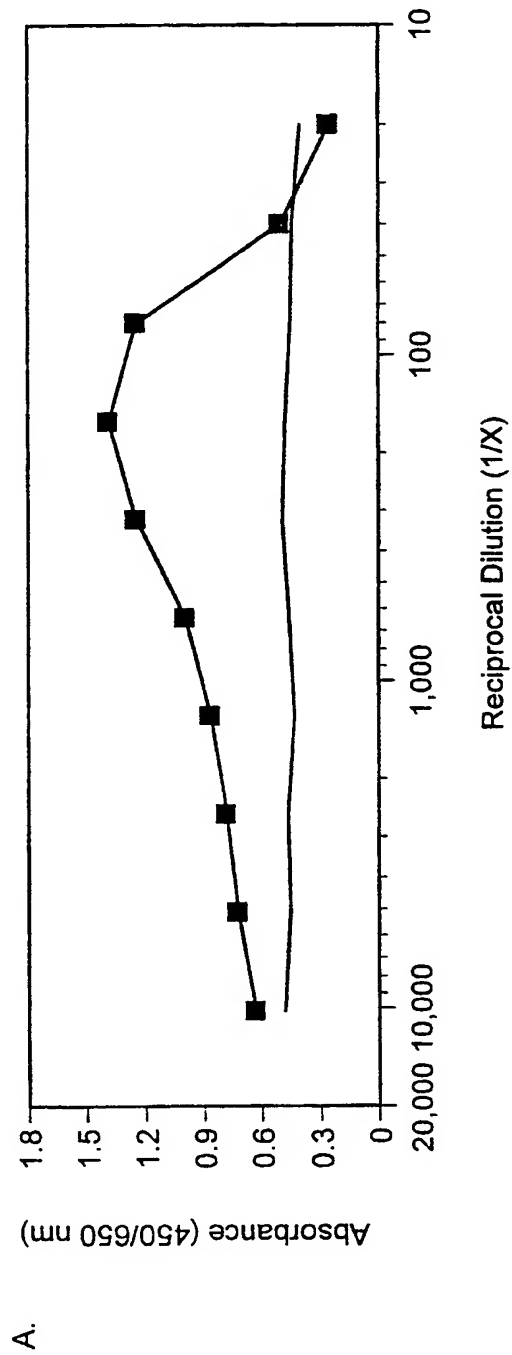


FIGURE 12

Figures 13A and 13B



Figures 14A and 14B

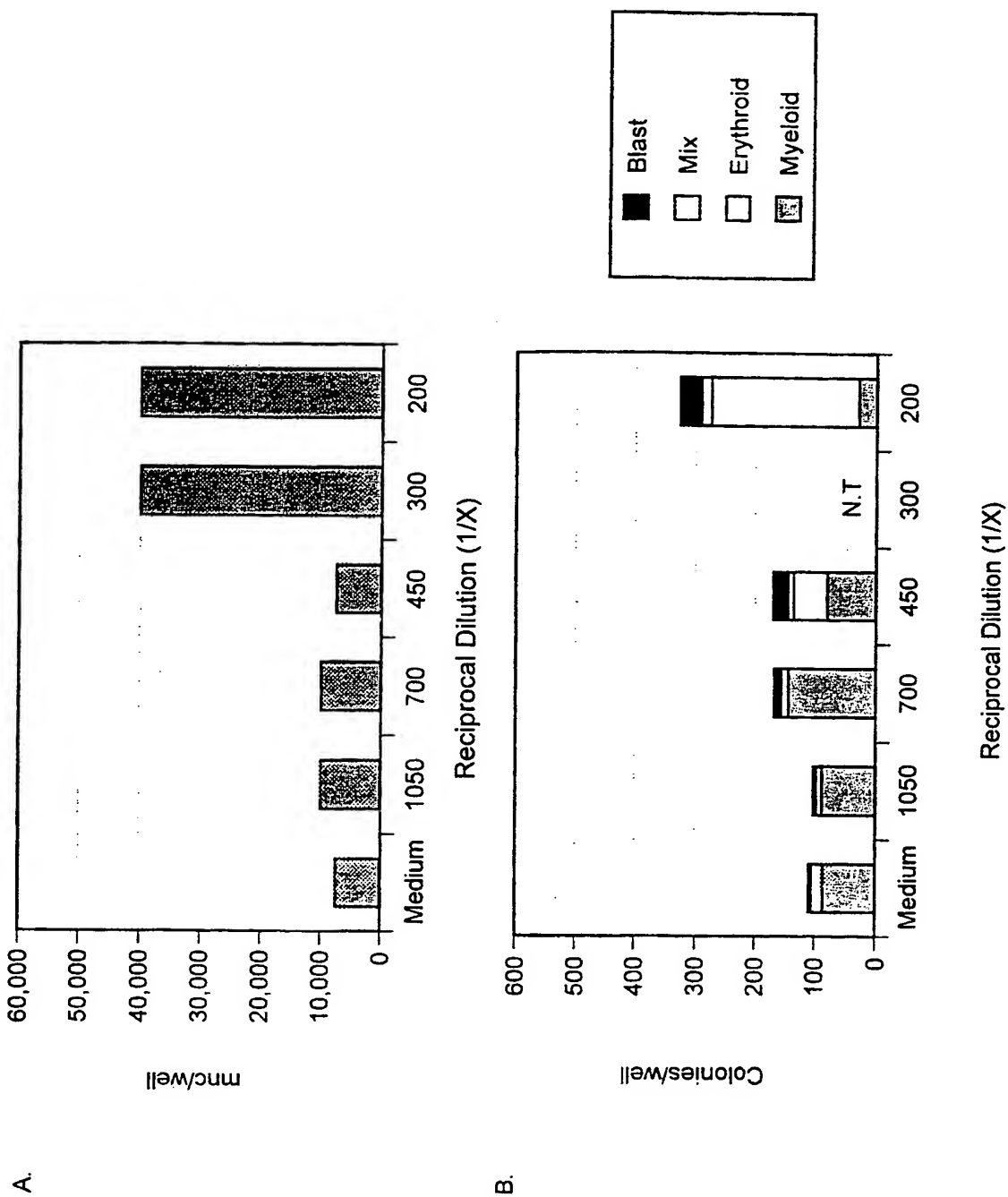
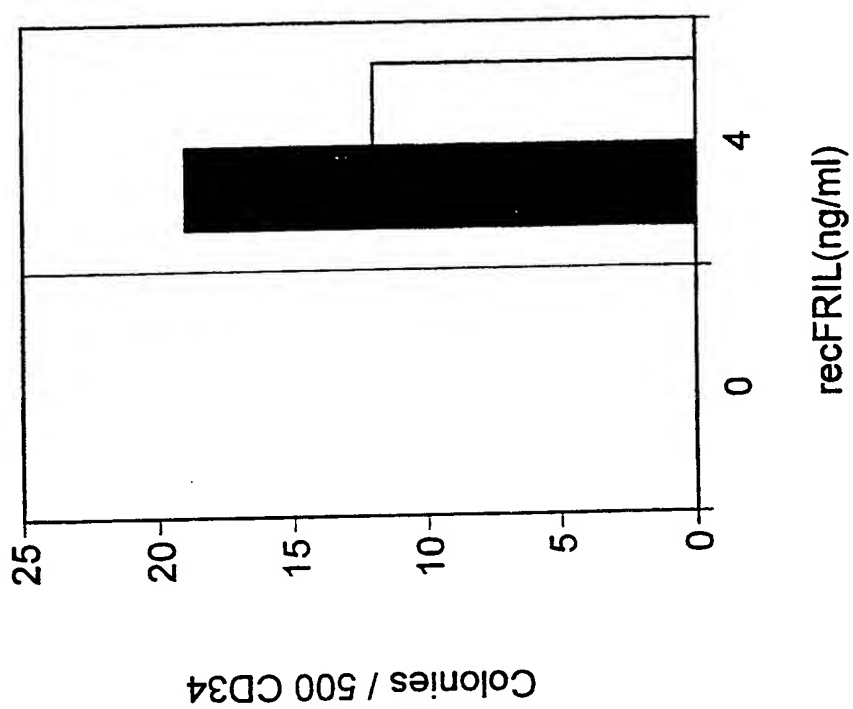


Figure 15



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/13046

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C12N 5/00, 15/00

US CL :435/455, 69.1, 320.1, 325; 536/23.1

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/455, 69.1, 320.1, 325; 536/23.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Database Medline on STN, US Patent and Trademark Office, (Arlington, VA, USA), No. 86196022, STUBBS et al. Production of Pea Lectin in Escherichia coli. Journal of Biological Chemistry. 15 May 1986, Vol. 261, No. 14, pages 6141-6144, see Abstract.	3, 5
X	VAN EIJSDEN et al. Mutational Analysis of Pea Lectin. Substitution of Asn125 for Asp in the Monosaccharide-Binding Site Eliminates Mannose/Glucose-Binding Activity. Plant Molecular Biology, 1992, Vol. 20, pages 1049-1058, see entire document.	3, 5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
*A* document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
*E* earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*g* document member of the same patent family
*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 15 SEPTEMBER 1998	Date of mailing of the international search report OCT 13 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer <i>Arthur Lawrence Fox</i> JILL D. MARTIN Telephone No. (703) 308-0196

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/13046

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ARAR et al. ERGIC-53, a Membrane Protein of the Endoplasmic Reticulum-Golgi Intermediate Compartment Is Identical to MR60, an Intracellular Mannose-Specific Lectin of Myelomonocytic Cells. The Journal of Biochemistry and Molecular Biology. 24 February 1995, Vol. 270, No. 8, pages 3551-3553, see entire document.	3, 5,-7, 9-17
X	Database Medline on STN, US Patent and Trademark Office, (Arlington, VA, USA), No. 97201486, VAN DAMME et al. Molecular Cloning of the Bark and Seed Lectins from the Japanese Pagoda Tree (Sophora Japonica). Plant Molecular Biology. February 1997, Vol. 33, No. 3, pages 523-536, see Abstract.	3, 5
A	US 5,545,820 A (GATEHOUSE et al.) 13 August 1996, see entire document.	3, 5

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/13046

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☒ Claims Nos.: 1, 2, 4, 8, 18-39  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:  
  
The claims recite SEQ ID NOS. without key words which could have been used for a word search. The sequences could not be searched because of the errors reported in the Raw Sequence Listing Error Report.
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
  
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US98/13046

## B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

MEDLINE, BIOSIS, CAPLUS, EMBASE, APS, WPIDS

search terms: lectins, hematopoietic cells, cell preservation, therapy, progenitors, legume, mannose, glucose, DNA, cDNA, nucleic acid, nucleotide, polynucleotide